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## Student Support Program Outputs, Outcomes and Impacts Report

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## **Student Support Program Outputs, Outcomes and Impacts Report**

*October 2019*

**The Robert B. Daugherty Water for Food Global Institute (DWFI) initiated its Postdoctoral and Student Support Programs in 2014. The following details their achievements.**

## Round One

The institute first provided undergraduate, graduate student and postdoctoral support to faculty who were selected following a call for proposals in 2014. Support was awarded for two postdocs, five graduate students, and two projects with undergraduate students. By FY19 a small amount of support continues for Francisco Munoz-Arriola's program. Outputs include presentations, grants and publications. The other faculty who have received support are: Vijendra Boken, UNK Geography & Earth Science; Carrick Detweiler, UNL Computer Science & Engineering; Trenton Franz, UNL School of Natural Resources; Patricio Grassini, UNL Agronomy & Horticulture; Alan Kolok, UNMC College of Public Health and UNO Biology; Robert Oglesby, UNL Earth & Atmospheric Sciences; Julie Shaffer, UNK Biology; and Harkamal Walia, UNL Agronomy & Horticulture. Outcomes include a significant leveraging of RBDF resources to implement the Platte Basin Timelapse project and achieve changes in knowledge, action and ultimately water and food security.

### Daugherty Fellows – Postdoctoral Positions

DWFI Faculty Fellows were invited to submit applications for Daugherty Fellows support. Daugherty Fellows postdoctoral positions were awarded to:

- **Francisco Munoz-Arriola**, Associate Professor in Hydroinformatics and Integrated Hydrology, UNL Biological Systems Engineering and School of Natural Resources, for the project: *Software Development for Water- and Agriculture-resources Data and Information Access: the case of the Water for Food Interoperability System (WaFIS)*.  
Dr. Munoz-Arriola has worked with a number of postdoctoral fellows throughout the course of this project funding period: **Carlos Ancona Villareal, Lorena Castro-Garcia, Martin Otto, Gengxin (Michael) Ou, Antonio Rosales Martinez, and Emannuelle Ruelas-Gomez.**



Gengxin (Michael) Ou

This team is working on the implementation of three modeling frameworks to assess water resiliency in agricultural working lands. These approaches include:

1. numerical modeling of flooding events in the High Plains, the Mexican Plateau (Mexico), and the Mumbai metropolitan area (India);
2. data-driven modeling applied to integrate groundwater, remote sensing, and field land surface hydrologic variables in Nebraska, resulting in the development of a forecasting platform (<https://nebraskagw.shinyapps.io/app1/>); and
3. statistical modeling applied in water resources planning in the Platte and Missouri River Basins, as well as in Mexico.

In addition to DWFI, these initiatives were funded by CONACYT (National Council for Science and Technology in Mexico), the Indian Department of Science and Technology, and the Indo-US Science and Technology Forum (through the WARI fellowships). This team is also working to develop the Water for Food Information System (WaFIS). Given the continuous changes in information technologies, the team has found a niche in “Hydroclimatic Analytics, Synthesis, and Modeling.”

#### Presentations:

- Castro-Garcia, L., G. Lopez-Morteo, and F. Munoz-Arriola. Water for Food Information System. *2014 Water for Food Conference*, Seattle, WA. October 21. (poster)
- Munoz-Arriola, F., A. Mohammad Abadi, K. Smith, M. Morton, D. Rico, L. Castro-Garcia, and G. Lopez-Morteo. Achieving Water Sustainability in the Era of Information Technology: The Role of Hydroinformatics and Integrated Hydrology. *2014 Water for Food Conference*, Seattle, WA. October 21. (poster)
- Castro---García, L, G. López---Morteo and F. Muñoz---Arriola. 2014. Water for Food Interoperability System (WaFIS). *2014 Water for Food Global Conference*. Seattle, Washington. October 22.
- Munoz-Arriola, F. From Paper to Big Data: Interoperability of Water-Food-Energy Data. Side Event. *2014 Water for Food Global Conference*. Seattle, Washington. October 22.
- Munoz-Arriola, F. R. Walko, A. Mohamad Abadi, L. Castro-Garcia. Toward Improving Predictability of Extreme Hydrometeorological Events in the Northern High Plains. *American Geophysical Union, Fall Conference*, San Francisco, CA. December 18, 2014.
- Rico, D., C. E. Ancona-Villareal, A. A. Rosales-Martínez, L. Castro, G Lopez Morteo, and F. Munoz-Arriola. Toward a Drought Seasonal Forecast in the Platte River Basin. *American Meteorological Society*, Phoenix, AZ. January 9th 2015. (poster)
- Castro-Garcia, L., G. Lopez-Morteo, and F. Munoz-Arriola. The Water for Food Interoperability System (WaFIS). *2015 Natural Resources Districts Legislative Conference*, Lincoln, NE. January 28, 2015. (poster)
- Munoz-Arriola, F., R. Stowell, C. Ancona-Villarreal, A. Rosales-Martinez, G. Lopez-Morteo, and D. Rudnick. Use of Interoperability/Information Systems to Inform Crop-, Cattle-, and Community-Decision Makers in a Changing Climate. *American Meteorological Society*, New Orleans, LA. January 14, 2016. (poster)
- Otte, M. and F. Munoz-Arriola. Representing Temperature and Precipitation Extremes by Dynamical Downscaling Using a Global, Multi-resolution Atmospheric Modeling System. *American Meteorological Society 30th Conference on Climate Variability and Change 2017*. Baltimore, US. July 28, 2017.

Publications: Livneh, B., T. Bohn, D. Pierce, F. Munoz-Arriola, B. Nijssen, R. Vose, D. Cayan, L. Brekke (2015): A spatially comprehensive, hydrometeorological data set for Mexico, the U.S., and southern Canada 1950-2013. *Nature - Scientific Data*, doi:10.1038/sdata.2015.42. <https://www.nature.com/articles/sdata201542>.

#### Additional Outputs (technological developments and transfers):

- Greer, H., S. Rehna, A. Kumar, M. Ou, and F. Munoz-Arriola. Editorial on Extreme events and climate change. *Lincoln Journal Star* (06/06/2017)
- Munoz-Arriola, F., L. Castro Garcia, and G. Lopez-Morteo (in progress). Water for Food Information System: From paper to Big Data. Funded by the Daugherty Water for Food Institute.
- Munoz-Arriola, F., A. Rosales, C.E. Ancona, and G. Lopez-Morteo (in progress). Water for Food Hydrological Seasonal Forecast System. Funded by the Daugherty Water for Food Institute and the Consejo Nacional de Ciencia y Tecnología-Mexico.
- Munoz-Arriola, F. and G. Lopez-Morteo. (1) Two data-collectors of data via web services programed in Python and Java; (2) six APIs that standardize/translate/deliver data in

multiple formats (CSV, JSON, netCDF, postgresQL, SPSS, HDF and text); (3) three apps (2 for smart phone and webpage); (4) analytics to address crop, livestock, and community needs.

Changes in Knowledge/Action: **Carlos Ancona Villareal** conducted research at UNL from January 2015 to June 2015. He graduated with a Masters in Computer Engineering from Universidad Autónoma de Baja California. He currently works as a Full Stack Engineer for an IT service provider. **Gengxin (Michael) Ou** currently works as a Research Assistant Professor at UNL, after working for five years as an Integrated Water Management Specialist at the Nebraska Department of Natural Resources.

- **Robert Oglesby**, Professor in Climate Modeling, Climate Change and Variability, UNL Earth & Atmospheric Sciences, for the project: *Leveraging DWFJ Resources to Address Water for Agriculture in Latin America Under a Changing Climate*.  
Postdoctoral Fellow: **Rachindra Mawalagedara**



Robert Oglesby is the lead Primary Investigator on a series of projects aimed at providing high-resolution (4 km) spatial climate change downscaling information to Latin America from the present as projected 50 years into the future. This is the spatial scale needed by those in the individual countries concerned with the many and specific impacts that will result under a changing climate.

In each case, with local participation, Oglesby and his team make a series of state-of-the-art climate change downscaling simulations. These are then used by the participants for impact studies relevant to their own region and area of interest, and also serve as the basis for scientific publications. The goal is not just to provide climate change downscaling scenarios but instead instruct the local participants to both make and use these scenarios to address their key issues and problems. These projects are the nexus of research, teaching, service and outreach. Climate change will impact the availability of water for agriculture in this region, flooding frequency and intensity, and water quality.

Rachindra Mawalagedara served as an interface between Oglesby's existing and future work and the institute and built new relationships and directions. More specifically, she:

1. Worked with the participants from the various Latin American countries to identify their specific climate impacts, vulnerability and adaptation needs, especially pertaining to water and food.
2. Worked with the participants to make the most effective use of the climate change downscaling results .
3. Integrated existing and future institute resources, personnel, and assets into all appropriate aspects of these Latin America projects.
4. Educated Inter-American Development Bank (IDB) staff, individual country government ministries, and NGOs that were encountered during this work about the institute and its capabilities.



#### Presentations:

- R. Oglesby, C. Rowe and R. Mawalagedara. Climate Model Simulation of Present and Future Extreme Events in Latin America and the Caribbean: What Spatial Resolution is Required? *UNESCO COP21 Climate Change Summit*. France. July 2015.
- Abadi, R. Oglesby, R. Mawalagedara, and C. Rowe. Evaluation of GCMs Historical Simulations of Monthly and Seasonal Climatology over Bolivia. *American Geophysical Union*. San Francisco. December 2015.
- Rowe, R. Oglesby, R. Mawalagedara, and A. Abadi. Climate Model Simulation of Present and Future Extreme Events in Latin America and the Caribbean: What Spatial Resolution is Required? *American Geophysical Union*. San Francisco. December 2015.

#### Publications:

- Impacts of Deforestation on Temperature and Precipitation in South and Southeast Asia (In re-review)
- R. Mawalagedara and R. Oglesby. Using High Resolution (4 km) Downscaling from WRF to Project Future Changes in Mean Climate for Sri Lanka (in review)
- A. Abadi, R. Oglesby, R. Mawalagedara, and C. Rowe. Evaluating 21st Century Climate Change for Bolivia: A Comprehensive Dynamical Downscaling Strategy Using the WRF Regional Climate Model (in progress)
- Numerous project reports, workshop reports, and internal documents.

Changes in Knowledge/Action: **Mawalagedara** performed all of her project functions in a superb manner. She handled most of the correspondence with consortium participants, who all spoke very highly of her. She supervised many of the analyses of the climate change downscaling simulations, as well as being an active participant in the preparation of the numerous internal reports and proceedings that resulted. **She is now a Lecturer for the Department of Geological and Atmospheric Sciences at Iowa State University.**

The project provided training in climate change downscaling to the Honduras National University in Tegucigalpa, Honduras in August 2014. It also provided country level training for Colombia in seasonal forecasting. The first workshop was held in July, 2015 in Bogota, Colombia with a follow-up planned. The team is also planning a similar workshop for Peru. The team is organizing country level training for Jamaica, Cuba, Hispaniola, Puerto Rico, the Windward and Leeward Islands, Trinidad and Tobago, Suriname, and Belize. Oglesby and Mawalagedara participated in *Observing & Modeling Climate Variability in the Intra-Americas Seas & Impacts on the Continental Americas & the Caribbean*, a CLIVAR Virtual Workshop held September 9-11, 2015. Oglesby and team held the "Program to Strengthen Institutional Capacity to better assess Climate Impacts in Latin America and the Caribbean (LAC)," Workshop 1: Initiation of the Regional Climate Change Consortium in Panama City, Panama in June 6-10, 2016.

Oglesby and team secured funding for the Program to Strengthen Institutional Capacity to better assess Climate Impacts in Latin America and the Caribbean (LAC) from the IAB (2/6/16-12/31/17). Doing so involved developing connections with eleven countries to secure their commitment to the Regional Consortium for Climate Change for Latin America and the Caribbean. As noted above, we held the First Workshop for the Regional Consortium June 6-10 in Panama City at CATHALAC Headquarters (Water Center for the Humid Tropics of Latin

America and the Caribbean). Ten countries attended. Four more workshops are planned between now and the end of 2017. Workshop 2 has been scheduled for November 14-18, 2016.

Caribbean Initiative - Oglesby and team are organizing country level training for Jamaica, Cuba, Hispaniola, Puerto Rico, the Windward and Leeward Islands, Trinidad and Tobago, Suriname, and Belize. This is anticipated to be a companion project to the LAC regional consortium and include the making of new downscaling simulations with a focus on the Caribbean islands.

Seasonal Climate Forecasting Initiative – This initiative started with the Colombia workshop held in July 2015. Oglesby and team are in discussions for follow-up work in Colombia and are also in discussions with the Ministry for the Environment of Peru for a similar Peruvian initiative.

### Daugherty Graduate Research Assistantships – MS and Ph.D. positions

DWFI Faculty Fellows and DWFI Faculty Affiliates were invited to submit applications for assistantship support. Five assistantships were awarded to:

- **Carrick Detweiler**, Associate Professor, UNL Computer Science and Engineering, for the project: *Enabling Sub-Surface Aerial Water Sampling for Water Management and Quality Analysis*. Masters Student: **James Higgins**, for an M.S. in Mechanical and Materials Engineering with a minor in Computer Science

**Presentations:** This work was presented in a variety of forums to engage community members, researchers, and practitioners. In addition to disseminating this work, these talks were used as opportunities to learn more about water sampling requirements from different groups. For example, when talking with faculty and students from the Ocean Engineering department at the University of Rhode Island, the team learned about the opportunity, need, and requirements for aerial water sampling of coastal wetlands, which is currently extremely challenging with existing techniques. The most relevant talks given were:

- Carrick Detweiler, "Using Drones for Water Sampling," Talk at Nebraska Surface Water Monitoring Council Meeting. Lincoln, NE, October 2014.
- James Higgins, "Robotic Water Sampling and Sensing in the Wild," Poster at NRD Legislative Conference. Lincoln, NE, January, 2015.
- Carrick Detweiler, "Bringing Drones Down to the Water," Talk at NRD Water Programs Conference. Kearney, NE, February, 2015.
- Carrick Detweiler, "Bringing Aerial Robots Closer to the Water: Sensing, Sampling, and Safety." Talk at University of Rhode Island, Ocean Engineering Seminar Series. Kingston, Rhode Island, April, 2015.
- James Higgins, "Aerial Robotics: Innovation, Productivity and Fun," Talk at St. John High School. St. John, Kansas, May, 2015.



*UAS in flight at Blue Oak Ranch Reserve*

- James Higgins, "Unmanned Environmental Monitoring and Sample Collection," DWFI Research Forum. May, 2015.
- James Higgins, "Robotic Mechanisms for Water Sample and Data Collection," DWFI Global Conference, Lincoln, NE. April, 2016.
- Carrick Detweiler, "Unmanned Environmental Monitoring and Sample Collection," DWFI Research Forum. May, 2016.

#### Publications:

- Chung, M.; Detweiler, C.; Hamilton, M.; Higgins, J.; Ore, J.-P.; Thompson, S. Obtaining the Thermal Structure of Lakes from the Air. *Water* 2015, 7, 6467-6482.  
<https://doi.org/10.3390/w7116467>
- J. Higgins and C. Detweiler, "The waterbug sub-surface sampler: Design, control and analysis," 2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Daejeon, 2016, pp. 330-337. doi: 10.1109/IROS.2016.7759075.  
<https://ieeexplore.ieee.org/document/7759075>
- THESIS: Higgins, J.K. Design, Testing and Evaluation of Robotic Mechanisms and Systems for Environmental Monitoring and Interaction (2016).  
<https://digitalcommons.unl.edu/mechengdiss/99/>

Changes in Knowledge/Action: James Higgins graduated in August 2016 with an M.S. in Mechanical and Materials Engineering and began working for a UAV (unmanned aerial vehicle) design company.

This project resulted in the development of an unmanned aerial vehicle (UAV) that is able to obtain sub-surface water samples from remote locations with minimal effort by operators. This technology enables scaling of water sampling to cover larger areas and/or higher resolution sampling at areas of interest. Tests of the technology are ongoing with partners at the University of Kansas and the University of California-Berkeley to answer context-specific questions related to water management and quality that cannot be answered today due to the cost and spatiotemporal limitations of current sampling techniques. The preliminary work conducted by James Higgins laid the groundwork for a nearly \$1 million U.S. Department of Agriculture grant (as part of the National Robotics Initiative) that began September of 2016 and targets sensing and sampling of wetlands environments. This grant involves another UNL Computer Science faculty member and a group of robotics and water scientists at the University of the Pacific in California.

Read a news article about the project [here](#).



- **Trenton Franz**, Associate Professor of Hydrogeophysics, UNL School of Natural Resources, for the project: *Improving soil moisture monitoring in agricultural systems using hydrogeophysics*.  
Masters Student: **William Avery**, for an M.S. from UNL School of Natural Resources



#### Presentations:

- *Global Water for Food Conference*, Seattle, Washington, October 19-22, 2014. (poster)
- *American Geophysical Union Conference*, San Francisco, California, December 15–19, 2014. Avery authored one poster and was listed as a co-author for two additional posters, one of which received an AGU Outstanding Student Presentation award.
- School of Natural Resources Elevator Speech Contest
- High Plains Aquifer: Sustainability for Food Production and Water Supply Symposium, March 19, 2015. (poster)
- Nebraska Water Center Faculty and Partner Retreat, Kearney, October 7, 2015. (poster)
- Nebraska Natural Resources Districts Legislative Conference, Lincoln, NE, January 27, 2016. (poster)
- DWFI Global Conference, Lincoln, NE, April, 2016. “The Cosmic-ray Neutron Soil Moisture Method: Applications for Large-Scale Precision Agriculture.” (poster)

#### Publications:

- Franz, T. E., T. Wang, W. Avery, C. Finkenbiner, and L. Brocca (2015), Combined analysis of soil moisture measurements from roving and fixed cosmic ray neutron probes for multiscale real-time monitoring. *Geophys. Res. Lett.*, 42, 3389–3396.  
(<http://onlinelibrary.wiley.com/doi/10.1002/2015GL063963/full>)
- Avery, W. A., Finkenbiner, C., Franz, T. E., Wang, T., Nguy-Robertson, A. L., Suyker, A., Arkebauer, T., and Munoz-Arriola, F.: Incorporation of globally available datasets into the cosmic-ray neutron probe method for estimating field scale soil water content, *Hydrol. Earth Syst. Sci. Discuss.*, doi:10.5194/hess-2016-92, in review, 2016.  
(<http://www.hydrol-earth-syst-sci-discuss.net/hess-2016-92/>)
- THESIS: Avery, W.A. The Cosmic-ray Neutron Probe Method for Estimating Field Scale Soil Water Content: Advances and Applications, A Thesis. *digitalcommons.unl.edu*, 2016.  
<https://digitalcommons.unl.edu/natresdiss/132/>

Changes in Knowledge/Action: **William Avery** successfully completed an M.S. degree in Natural Resources after defending his thesis in May 2016 and graduated in August 2016. He spent six months in Vienna, Austria for an internship with the Food & Agriculture Organization of the United Nations and the International Atomic Energy Agency (IAEA). He currently works as a consultant for IAEA (Jul 2016 – Present).

William was instrumental in helping set up ten stationary cosmic-ray neutron probes across the state at five different study sites near Mead, Waco, Grand Island, Sutton, and Brule. These five study sites have formed the basic infrastructure in Professor Franz’s lab to host various undergraduate and graduate research projects for years to come. The lab is working with individual producers at the Waco (Romher Farms), Sutton (Paulman Farms), Brule (Armstrong Farms) study

sites, and The Western Irrigation Project (The Nature Conservancy). The lab is working with the Eastern Nebraska Research and Extension Center at the Mead study site and West Center Research and Extension Center in North Platte (Daran Rudnick). At the Grand Island site, the team is working in conjunction with the Platte River Recovery Implementation Program through the Headwaters Corporation.

In addition to setting the stationary probes, William Avery collected the majority of cosmic-ray rover surveys at the various study sites. Between 2014-2016 Avery completed 30 surveys at Waco, ten at Grand Island and Brule, and ten at Sutton. He served as a key data collector and team leader helping manage the two undergraduate workers and other MS student.

- **Patricio Grassini**, Associate Professor, UNL Agronomy & Horticulture, for the project: *Revealing the links between crop production, irrigation and inter-annual changes in groundwater levels in Nebraska*. Masters Student: **Kate Gibson** (formerly Boone), UNL Agronomy & Horticulture



#### Presentations:

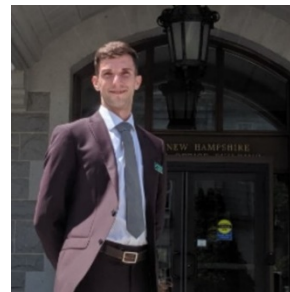
- Nebraska Natural Resources Districts Legislative Conference, Lincoln, NE, January 28, 2015.
- DWFI Student Support Research Forum, Lincoln, NE, May 28, 2015. "Impact of Irrigation on Local and Regional Groundwater Dynamics in Nebraska."
- Nebraska Water Center Faculty and Partner Retreat, Kearney, NE, October 7, 2015.
- Nebraska Natural Resources Districts Legislative Conference, Lincoln, NE, January 27, 2016.
- DWFI Global Conference, Lincoln, NE, April, 2016. "How much irrigation can be saved in Nebraska without hurting yields?"
- DWFI Research Forum, Lincoln, NE, May 12, 2016. "Benchmarking On-farm Irrigation Management in Nebraska."

#### Publications:

- Farmaha BS, Lobell DB, Boone K, Cassman KG, Yang, SH, Grassini P, 2016. Contribution of persistent factors to yield gaps in high-yield irrigated maize. *Field Crops Research* 186, 124-132. <https://doi.org/10.1016/j.fcr.2015.10.020>
- THESIS: Gibson, K.E.B. 2016. More Crop per Drop: Benchmarking On-farm Irrigation Water Use for Crop Production. MS Thesis. University of Nebraska, Lincoln, NE. <https://digitalcommons.unl.edu/agronhortdiss/107/>

Changes in Knowledge/Action: **Kate Gibson** graduated in August 2016 and joined DWFI as a program associate working under the supervision of Nick Brozovic. She was recently promoted to research program manager.

- **Alan Kolok**, Director, Center for Environmental Health and Toxicology, UNMC College of Public Health, and Professor, UNO Biology, for a project to study the pressure that agrichemicals exert on water resources.  
Ph.D. Student: **Jonathan Ali**, for a Ph.D. from the UNMC College of Public Health (Note: awarded subsequent funding as part of Round Three)



#### Presentations:

- DWFI Student Support Research Forum, Lincoln, NE, May 28, 2015. "Novel assessment tools: Utilizing citizen science and sentinel organisms to detect agrichemical runoff."
- Ali J.M., et al. (Dec 2015) Nebraska Chapter of the American Fisheries Society Meeting- Streams and Rivers Technical Meeting, Gretna, NE, USA.
- Ali J.M., et al. (Nov 2015) Society of Environmental Toxicology and Chemistry 2015 North America 36th Annual Meeting, Salt Lake City, UT, USA.
- Ali J.M., et al. (Apr 2016). Sustainability Launchpad: Accelerating Innovative Urban Ideas. Omaha, NE, USA. 1st Place Graduate Student Poster Competition.
- Ali J.M., et al. (Apr 2016). 2016 Water for Food Global Conference, Lincoln, NE, USA.
- DWFI Research Forum, Lincoln, NE, May 12, 2016. "Biomonitoring Watersheds in Nebraska and Chile: Advancing toxicity studies of agricultural runoff both near and far."
- Ali J.M., et al. (Jan 2016). Natural Resource Department: Nebraska Natural Resources Commission Meeting. Lincoln, NE, USA.
- Ali J.M., et al. (Oct 2015). Nebraska Environmental Health Association 2015 Meeting, Ashland, NE, USA.
- Rakestraw M.J., et al. (Nov 2015). Society of Environmental Toxicology and Chemistry 2015 North America 36th Annual Meeting. Salt Lake City, UT, USA.
- Kolok A.S., et al. (Nov 2015). Society of Environmental Toxicology and Chemistry 2015 North America 36th Annual Meeting. Salt Lake City, UT, USA.
- Rakestraw M.J., et al. (Oct 2015). Nebraska Environmental Health Association 2015 Meeting, Ashland, NE, USA.
- Zhang Y., et al. (Jun 2015). Association of Environmental Engineering and Science Professors 2015 Research and Education Conference. New Haven, CT, USA.
- Ali JM and Kolok AS (2014). Society of Environmental Toxicology and Chemistry 2014 North America Annual Meeting, Vancouver, BC. "Pesticide runoff in the Elkhorn River, Nebraska, USA: Temporal variation in chemical occurrence and biological impact." (poster)
- Ali JM, Lieurance DM, and Cipollini D (2013). Florida Exotic Pest Plant Council 2013 Annual Meeting, Panama City, FL. "Effects of soil biota and rhizosphere extract from non-native *L. maackii* on the native *I. capensis*." (poster)
- Apr 2015, Nebraska SciFest, University of Nebraska at Omaha, Omaha, NE. "Nebraska Science Fest: Testing the Waters"
- Feb 2015, Nebraska Watershed Network, Wahoo High School, Wahoo, NE. "What's in Your Watershed"
- Nov 2014, Nebraska Watershed Network, Barbara Weitz Community Engagement Center, Omaha, NE. "What's in Your Watershed"
- Oct 2014, University of Nebraska Medical Center High School Alliance, Barbara Weitz Community Engagement Center, Omaha, NE. "Environmental Health Science"

- Ali J.M. Biomonitoring Watersheds in Nebraska and Chile.  
[https://www.youtube.com/watch?v=8SlgLaO\\_VXw](https://www.youtube.com/watch?v=8SlgLaO_VXw)

#### Publications:

- Ali, J.M., Sangster, J., Snow, D.D., Bartelt-Hunt, S.L., Kolok, A.S. (2017) Compensatory response of fathead minnow larvae following a pulsed in-situ exposure to a seasonal agricultural runoff event. *Science of the Total Environment*, 603–604: 817–826.  
<http://dx.doi.org/10.1016/j.scitotenv.2017.03.093>.
- Ali J.M., Farhat Y.A. and A.S. Kolok. (2016) Biological Impacts in Fathead Minnow Larvae Following a 7-Day Exposure to Agricultural Runoff: A Microcosm Study. *Bulletin of Environmental Contamination and Toxicology*, 96(4):432-7. <https://doi.org/10.1007/s00128-016-1762-2>.
- Ali JM and AS Kolok. (2015). On-site, serial exposure of female fathead minnows to the Elkhorn River, NE, USA spring agrichemical pulse. *Environmental Toxicology and Chemistry*, doi: 10.1002/etc.2928. <https://doi.org/10.1002/etc.2928>.
- Ali J.M., Herrmann K.M.K., Rakestraw M.J. and A.S. Kolok. (2016) Citizen-based scientific data collection: Fact or fiction? *Integrated Environmental Assessment and Management*, 12(2), 400–402. <https://doi.org/10.1002/ieam.1750>.
- Sangster J.L., Ali J.M., Snow D.D., Kolok A.S. and S.L. Bartelt-Hunt. Bioavailability and fate of sediment-associated progesterone in aquatic systems. *Environmental Science and Technology*, 50(7), 4027–4036. <https://doi.org/10.1021/acs.est.5b06082>.
- Zhang, Y.; Krysl, R.G., Ali, J.M., Snow, D.D., Bartelt-Hunt, S.L. and Kolok, A.S. (2015). Impact of sediment on agrichemical fate and bioavailability to adult female fathead minnows: A field study. *Environmental Science and Technology*, 49(15): 9037–9047.  
<https://doi.org/10.1021/acs.est.5b01464>.
- Jurcsisn JG, Pye RL, Ali JM, Barr BL and CN Wyatt. (2015). The CamKK $\beta$  inhibitor STO609 causes artifacts in Ca<sup>2+</sup> imaging and inhibits BKCa in mouse carotid body type I cells. *Advances in Experimental Medicine and Biology*. 860:17-24. [https://doi.org/10.1007/978-3-319-18440-1\\_3](https://doi.org/10.1007/978-3-319-18440-1_3).
- Ali JM, Lieurance DM, and D Cipollini. (2015). Soil biota affect mycorrhizal infection and growth of *Impatiens capensis* and alter the allelopathic effects of *Lonicera maackii*. *Journal of the Torrey Botanical Society*, 142(1), 1-11. <https://doi.org/10.3159/TORREY-D-14-00009.1>.
- DISSERTATION: Ali, Jonathan, "Organizational Effects of Defeminizing Toxicants: Lessons Learned From an Environmental Sentinel Organism, The Fathead Minnow." (2017). Theses & Dissertations. 231. <https://digitalcommons.unmc.edu/etd/231>.

Changes in Knowledge/Action: Jonathan Ali graduated from UNMC in December 2017. He has gone on to work as a Postdoctoral Researcher in Civil Engineering at UNL, an Instructor of Biology at UNO, and currently as an Environmental Toxicologist at New Hampshire Department of Environmental Services (Oct 2018 – present). For more information, see Round Three.

- **Harkamal Walia**, Associate Professor, UNL Agronomy & Horticulture, for the project: *Improving drought tolerance of wheat through more adaptive roots*.

Ph.D. Student: **Sarah Blecha**, UNL Agronomy & Horticulture



#### Presentations:

- 2014 – Plant and Animal Genome Meeting, San Diego; Nexus: Water, Food, Climate and Energy Conference, Chapel Hill; University of California, Riverside; Gordon Research Conference for Salt and Water Stress in Plants, Maine
- 2015 – Colorado State University, Fort Collins
- Nebraska Natural Resources Districts Legislative Conference, Lincoln, NE, January 28, 2015.
- Nebraska Natural Resources Districts Legislative Conference, Lincoln, NE, January 27, 2016.
- DWFI Global Conference, Lincoln, NE, April, 2016. “Physiological and Genetic Investigation of Spring Wheat cv. Pavon Under Limited-Water Condition”

#### Publications:

- Bai, G., Blecha, S., Ge, Y., Walia, H., Phansak, P. Characterizing Wheat Response to Water Limitation Using Multispectral and Thermal Imaging. (2016) Transactions of the ASABE. 60(5): 1457-1466. <http://dx.doi.org/10.13031/trans.11967>.
- DISSERTATION: Blecha, Sarah, "Addressing the Challenges Facing Wheat Production: Nebraska and International Breeding Efforts" (2019). *ETD collection for University of Nebraska - Lincoln*. AAI13861883. <https://digitalcommons.unl.edu/dissertations/AAI13861883>.

Changes in Knowledge/Action: **Sarah Blecha** entered the Doctor of Plant Health Program in December 2016, and graduated in May 2019.

These multidisciplinary experiments will develop a more robust and flexible phenotyping platform and gain a temporal high-resolution characterization of drought stress responses for wheat genotypes, which differ in drought tolerance. Experiments include the transgenic wheat lines for drought tolerance. This research generated new data that justified the filing of a non-provisional, full patent application for a gene that is involved in regulating root biomass under drought stress (filed in Nov., 2014 by UNL).



## Daugherty Undergraduate Scholars

DWFI Faculty Fellows and DWFI Faculty Affiliates were invited to submit applications for undergraduate research assistantship support. Support for six students (to be hired post-award) was awarded to:

- **Vijendra Boken**, Professor, UNK Geography and Earth Science, for a project to study the link between soil moisture estimates and global warming for Nebraska using satellite data.  
Students: **Areeb Hossain, Ben Wagner, Emily Kaslon, Spencer Sydow, Tayler McPeak**

### Presentations:

- Hossain, Areeb S. and Boken, V. Sociology, Geography & Earth Science, University of Nebraska at Kearney. *Examining the Impact of Irrigation on Temperatures in Nebraska Counties*.
- McPeak, T. and Boken, V. (2015) Assessing impact of irrigation on global warming. *International Conference on Climate Impacts and Responses*, Vancouver, BC, 10-11 April 2015.

Changes in Knowledge/Action: Tayler McPeak graduated in May 2016 and Emily Kaslon in May 2016.

- **Michael Farrell and Mike Forsberg**, Assistant Professors of Practice, UNL Agricultural Leadership, Education and Communication, for the project: *Platte Basin Timelapse*.  
Students: **Merika Andrade, Joe Arneson, Grace Bullington, Ethan Freese, Carlee Koehler, Mariah Lundgren, Alex Lundvall, Zoe Mays, Grant Reiner, Andrew Wentz** (Note: awarded subsequent funding as part of Round Four)

Presentations: Key to this Platte Basin Timelapse Project's success so far has been recruiting and training a pool of emerging talented young people through paid internships.

- *Global Water for Food Conference*, Seattle, Washington, October 19-22, 2014 (poster)
- DWFI Student Support Research Forum, Lincoln, NE, May 28, 2015.
- Sunday with a Scientist, Lincoln, NE, June 12, 2016.
- Timelapse videos available at: <http://plattebasintimelapse.com/>

Changes in Knowledge/Action: Mariah Lundgren graduated December 2014 and is now working part-time for the project supervising interns. Joe Arneson graduated May 2015. (additional reporting, Round Four). The project has established funding relationships with the Nebraska Corn and Soybean Boards and several others. (additional reporting, Round Four)

- **Julie Shaffer**, Professor, UNK Biology, to characterize abiotic and biotic components of lakes in the Willow Creek drainage of Brown County, Nebraska.  
Students: **Alyssa Dillon, Seth Springer**

### Presentations:

- Dillon, A., Shaffer, J., Peterson, B.C., Koupal, K.D., and Graham, K. (2015) Influence of common carp (*Cyprinus carpio*) on abiotic and biotic parameters within Nebraska's Sandhill lakes. Nebraska American Fisheries Society Meeting, Nebraska City, NE. *poster presentation*

- Dillon, Alyssa, and Shaffer, Julie. (2015) Investigation of abiotic and biotic parameters in three Nebraska's Sandhill lakes within the same drainage. 17th Annual University of Nebraska at Kearney Student Research Day, Kearney, NE. *poster presentation*
- Dillon, A. (2015) Influence of common carp (*Cyprinus carpio*) on abiotic and biotic parameters within Nebraska's Sandhill lakes. UNK Biology Senior Research Project. *oral presentation*
- Shaffer, Julie (May, 2015) Nebraska sandhills lakes. Nebraska Department of Environmental Quality Annual Meeting (invited presentation), Kearney, NE. *oral presentation*

Changes in Knowledge/Action: Two UNK undergraduate students conducted field research – Alyssa Dillon and Seth Springer.

## Round Two

In 2015 graduate student support was provided to faculty who were selected following a call for proposals. Faculty Fellows secured additional funds on their own to support the students, matching DWFI funds one-to-one. By FY19 support continues for one of the seven graduate students originally awarded support.

### Daugherty Graduate Research Assistantships – MS and Ph.D. positions

DWFI Faculty Fellows were invited to submit applications for student support up to \$16,000, with additional student funding secured by the Faculty Fellow. Seven assistantships were awarded to:

- **Shannon Bartelt-Hunt**, Professor, UNL Civil Engineering, for a project to evaluate the direct effects of climate and the indirect effects of climate-induced animal agriculture clustering on the fate of trace organic compounds originating from production agriculture.  
Ph.D. Student: **Renys Barrios**, for a Ph.D. in Environmental Engineering



Over the grant period, we have completed large scale column studies of atrazine transport in soils collected from our study site and have initiated large scale column studies for antibiotic transport and to evaluate changes in microbial community structures. We hosted one WARI intern: Omkar Goankar and one undergraduate student researcher, Claire Devereaux, who participated in the research activities of this project. This work has been highlighted in numerous media outlets including the American Society of Civil Engineers magazine and Nebraska Education Television (NET). In 2018 we presented the results of this research to a groundwater planning and management organization in the state of Minnesota and the Water for Food Research Forum, April 26, 2018.

#### Presentations:

- Barrios, R.; Gaonkar, O.; Bartelt-Hunt, S.L.; Li, X.; Snow, D.D.; Li, Y. (2018). Influence of climate change on subsurface atrazine degradation and transport. American Chemical Society Spring Meeting, New Orleans, LA, March 18-21, 2018.
- Bartelt-Hunt, S.L. and Thompson, E. (2017). The influence of agricultural clusters on groundwater quality under climate change. Nebraska Water Symposium, Lincoln, NE October 26-27, 2017.
- Barrios, R.; Bartelt-Hunt, S.L.; Li, X.; Li, Y.; Zhang, Y.; Gani, K.M. (2017). Influence of Climate Change on Trace Organic Fate in the Subsurface. AEESP Research and Education Conference, Ann Arbor, MI June 21-23, 2017.
- Akbariyeh, S., Wang, T., Bartelt-Hunt, S.L., Li, Y. (2016). Application of Inverse Modeling to Estimate Groundwater Recharge under Future Climate Scenarios. American Geophysical Union Fall Meeting, San Francisco, CA, December 12-16, 2016.
- Barrios, R. (2016). Influence of Climate Change on Trace Organic Loading Rates to Groundwater. DWFI Research Forum, Lincoln, NE, May 12, 2016.
- Akbariyeh, S., Snow, D., Bartelt-Hunt S.L., Li, X., and Li, Y. (2016). Three dimensional modeling of agricultural contamination of groundwater: a case study in the Nebraska

Management Systems Evaluation Area (MSEA). Water, Sustainability and Climate Investigator's Meeting, Washington D.C., March 9-11, 2016.

- Bartelt-Hunt, S.L. and Thompson, E. (2016). Influence of climate on the fate of trace organics in groundwater. Water, Sustainability and Climate Investigator's Meeting, Washington D.C., March 9-11, 2016.
- Akbariyeh, S., Snow, D., Bartelt-Hunt S.L., Li, X., and Li, Y. (2015). Three dimensional modeling of agricultural contamination of groundwater: a case study in the Nebraska Management Systems Evaluation Area (MSEA). American Geophysical Union Fall Meeting, San Francisco, CA, December 14-18, 2015.
- Bartelt-Hunt-S.L. (2015) The effect of climate on the fate of trace organics in groundwater. Groundwater Foundation National Meeting, Lincoln, NE, Oct. 21-22, 2015.

#### Publications:

- Barrios, R.; Gaonkar, O.; Snow, D.D.; Li, Y.; Li, X.; Bartelt-Hunt, S.L. Enhanced Biodegradation of atrazine at high infiltration rates in agricultural soils. (2019) *Environ. Sci.: Processes Impacts*, 21: 999-1010. <http://dx.doi.org/10.1039/C8EM00594J>.
- Barrios, Renys & Akbariyeh, Simin & Bartelt-Hunt, Shannon & Li, Xu & Li, Yusong & Zhang, Yun & Gani, Khalid. (2017). Influence of Climate Change on Trace Organic Fate in the Subsurface. University of Michigan, Ann Arbor., 2017 AEESP Research and Education Conference.  
[https://www.researchgate.net/publication/318921163\\_Influence\\_of\\_Climate\\_Change\\_on\\_Trace\\_Organic\\_Fate\\_in\\_the\\_Subsurface](https://www.researchgate.net/publication/318921163_Influence_of_Climate_Change_on_Trace_Organic_Fate_in_the_Subsurface).
- Barrios, R.; Akbariyeh, S.; Bartelt-Hunt, S.L.; Li, Y.; Li, X.; Snow, D.D.; Tang, Z.; Rosenbaum, D.; Park, J.; Thompson, E. (2017). Groundwater quality, trace organic fate and climate change (in preparation for submission in August 2017).
- Akbariyeh, S.; Bartelt-Hunt, S.L.; Snow, D.D.; Li, X.; Tang, Z.; and Li, Y. Numerical modeling of nitrate leaching: Interaction of groundwater vertical flux and infiltration of nitrate in a 3-D soil profile. *Vadose Zone Journal*, (in review).

Changes in Knowledge/Action: **Renys Barrios** continues to work as a Graduate Research Assistant at UNL and complete his PhD program. His dissertation is titled *Influence of Climate and Land Use on Trace Organic Loading Rates to Groundwater*.

- **Junke Guo**, Associate Professor, UNL Civil Engineering, for the project: *Determinaton of River Ecological Discharge from Navier-Stokes-Forchheimer Equation*.  
Ph.D. Student: **Narendra Kumar Patel**, for a Ph.D. in Civil Engineering (specializing in Hydraulics and Water Resources)

As of May 2018, Narendra Kumar Patel continues his research by collecting data, analyzing data, and writing reports. (*One year he did now draw down his award, thus it carried over.*)

The recent research based on the Navier-Stokes-Forchheimer equation is listed below. Research on “flow between parallel disks” and “river flow with vegetation bed” makes sure that we have an understanding of the methodology and our current research work will be successful by producing deliverable results. The first reference below provides an exact



analytical solution for vegetated flow and is mostly related to the proposed research work; the second solves a similar problem to the proposed research.

1. Guo, J., Zhang, J. (2016). Velocity distribution in laminar and turbulent vegetated flows. *Journal of Hydraulic Research*.
2. Guo, J. (2015). Exact solution to Navier-Stokes equation for radial flow between parallel disks. *Journal of Hydraulic Research*.

#### Presentations:

- 2016 Water for Food Global Conference (poster)
- Water for Food Institute Research Forum, May 12, 2016, UNL
- Water for Food Research Forum, April 26, 2018.
- Narendra Patel also presented his research at the 8th International Symposium on Environmental Hydraulics, held June 4-7, 2018 at the University of Notre Dame, Indiana, USA.

#### Publications:

Changes in Knowledge/Action: **Narendra Kumar Patel** continues to work as a Graduate Research Assistant at UNL. He anticipates completing his PhD in 2019.

This research helped determine the percentage of water flowing below the river bed. This is the additional water which should be released from a dam to maintain the ecosystem on the downstream side. The study also helps water managers know the water loss in natural channels with porous beds.

- **Adam Liska**, Associate Professor, George Dempster Smith Chair of Industrial Ecology, UNL Biological Systems Engineering and Agronomy & Horticulture, for the project: *Climate Change Feedbacks via Insurance*. Masters Student: **Eric Holley**, for an M.S. in Natural Resource Sciences (Human Dimensions Emphasis) from UNL School of Natural Resources.



#### Presentations:

- DWFJ Research Forum, Lincoln, NE, May 12, 2016. "Climate Change Feedbacks via Insurance."

#### Publications:

- Eric R. Holley, Adam J. Liska, Michael Hayes, Max Ruldoph, Geoffrey C. Friesen, Donald E. Wilhite, "Climate Change Feedbacks Via Insurance," in process, to be submitted to *Nature Climate Change* or *Climate Change*
- Published in *Understanding and Assessing Climate Change: Implications for Nebraska. A Synthesis Report to Support Decision Making and Natural Resource Management in a Changing Climate*, ed. Deborah J. Bathke, Robert J. Oglesby, Clinton M. Rowe, and Donald A. Wilhite (Lincoln, NE: The University of Nebraska-Lincoln, 2014), pp. 59–60.  
<https://digitalcommons.unl.edu/bseliska/20/>.
- Adam J. Liska, Tyler R. White, Eric R. Holley & Robert J. Oglesby (2017) Nuclear Weapons in a Changing Climate: Probability, Increasing Risks, and Perception, *Environment: Science and*



*Policy for Sustainable Development*, 59:4, 22-33.  
<https://doi.org/10.1080/00139157.2017.1325300>.

- THESIS: Holley, E.R. (2016). *Adaptation to climate change via insurance and financial incentives* (Unpublished Master's Thesis). University of Nebraska-Lincoln, Lincoln NE.  
<https://digitalcommons.unl.edu/embargotheses/95/>

Changes in Knowledge/Action: **Eric Holley** graduated in August 2016 and is pursuing a Ph.D. in the same program. His research has evolved to focus on an investigation of the climate and agricultural risks associated with nuclear energy. "These problems have very broad negative implications for agriculture, and we hope to lead new research into these issues with partners at the National Strategic Research Institute at the University of Nebraska."

- **Patrice McMahon**, Tenure Professor, UNL Political Science, for the project: *Transnational Actors and Water Security*.  
Ph.D. Student: **Maria Benes**, for a Ph.D. in Political Science (specializing in Comparative Politics and International Relations)



Presentations:

- Benes, M. "Water from the Spider's Web: A Review of the Literature on Transnational Networks and Water Security," International Studies Association Midwest Conference, St. Louis, MO, November 20-22, 2015
- McMahon, P. Krakow, Poland: Cooperation Rules: Insights on Water and Conflict from International Relations" Interdisciplinary Conference on New Security Issues, June 2016
- McMahon, P. and Benes, M., "New Partnerships in Water Security," at World Conference on Humanitarian Studies, Addis Abba, Ethiopia, March 2016
- McMahon, P and Benes, M. invited talk, "Moving Beyond Borders: Transnational Actors, Networks and Water Security," Water Centric Cities Conference, University of Wisconsin-Milwaukee, April 2016
- Benes, M. and McMahon, P. "Moving Beyond Borders: Transnational Actors, Networks and Water Security, Water for Food Institute Research Forum, University of Nebraska-Lincoln, May 12, 2016
- McMahon, P, "Ethiopia: International Actors and Lessons Learned," panel organizer and panelist, DWFI Global Conference, Lincoln, April 10, 2017.
- McMahon, P, "The NGO Game: Nongovernmental Organizations in Post-Conflict Peacebuilding and Water Security" Hebrew University, Jerusalem, Israel. May 2017
- Benes, M. "Moving Beyond Borders: Transnational Actors, Networks and Water Security," DWFI Research Forum, Lincoln, NE, May 11, 2017.
- Benes, M. "Water from the Spider's Web: Has the UN-Water Network Met Its Goals?," Midwest
  - Political Science Association Conferences, Chicago, IL, April 2018
- Benes, M. "Global Water Strategy: Assessing the First 15 Years of UN-Water," NU Robert B. Daugherty Water for Food Institute Research Forum, University of Nebraska-Lincoln, April 2018

#### Publications:

- McMahon, P. "Cooperation Rules: Insights on Water and Conflict from International Relations," in *Water Security and Peacebuilding in the Middle East*, edited by Jean Cahan Forthcoming: Anthem Press.
- Benes, M. "The Many Faces of 'Water Security: Diffusion of Water Security Norms Within the UN-Water Network,'" preparing this paper for potential publication
- Benes, M. and McMahon, P, "An Ethnographic Case Study of the Ethiopian Water Security Network"

Changes in Knowledge/Action: Maria Benes is continuing to work on her doctorate in political science at UNL. Her professional specializations are transnational water networks, international relations and comparative politics. She also enjoys teaching human rights, international law, international relations and public policy.

Benes visited Addis Abba, Ethiopia to do background research and interviews with international and local NGOs, foundations and international organizations working on water security. McMahon and Benes worked separately, together and with an international group from Ethiopia on grants, publications, and presentations related to water security and water networks. Benes also organized monthly interdisciplinary meetings on human security and water with faculty and graduate students in the Political Science Department (Fall 2015).

McMahon, P., Shank, N, Beyene, Z, Beyene, S, Benes, M., Women's Empowerment Network, submitted a grant to USAID, June 2016. Benes was invited to join the DWFI policy team to collaborate on a water security and entrepreneurship project that focuses on networks and grassroots coalitions in the High Plains region.

- Mehmet C. Vuran, Susan J. Rosowski Professor, UNL Computer Science and Engineering, for the project: *Taking Soil to the Cloud: Advanced Wireless Underground Sensor Networks for Real-time Precision Agriculture*.  
Ph.D. Student: **Abdul Salam**, for a Ph.D. in Computer Engineering



#### Presentations:

- DWFI Research Forum, Lincoln, NE, May 12, 2016. "Taking Soil to the Cloud: Advanced Wireless Underground Sensor Networks for Real-time Precision Agriculture."
- Water for Food Research Forum, April 26, 2018.

#### Publications:

- M. C. Vuran, A. Salam, R. Wong, and S. Irmak "Internet of Underground Things in Precision Agriculture: Architecture and Technology Aspects", under review in *Ad Hoc Networks* (Elsevier), Aug 2018.
- Salam, M. C. Vuran, "Wireless Underground Channel Diversity Reception With Multiple Antennas for Internet of Underground Things", in *Proc. of the IEEE ICC 2017, Paris, France*, May 2017.

- Salam, M.C. Vuran, and S. Irmak, "Pulses in the Sand: Impulse Response Analysis of Wireless Un-derground Channel", in Proc. of the *35th IEEE International Conference on Computer Communications (IEEE INFOCOM 2016)*, April 2016, San Francisco, CA, USA.
- Salam and M.C. Vuran, "Impacts of Soil Type and Moisture on the Capacity of Multi-Carrier Modulation in Internet of Underground Things", to appear in Proc. of the *25th International Conference on Computer Communication and Networks (ICCCN 2016)*, August 2016, Waikoloa, Hawaii, USA. **The paper received the Best Student Paper award at ICCCN 2016.**
- DISSERTATION: Salam, Abdul, "Pulses in the Sand: Long Range and High Data Rate Communication Techniques for next Generation Wireless Underground Networks" (2018). ETD collection for University of Nebraska - Lincoln. AAI10826112. <https://digitalcommons.unl.edu/dissertations/AAI10826112>.

Changes in Knowledge/Action: **Abdul Salam** earned his Ph.D. and joined Purdue as an Assistant Professor (Fall 2018). More information available [here](#).

During his research, Abdul Salam has developed the first cognitive radio-enabled wireless underground communication testbed in South Central Agriculture Lab, Clay Center, NE. This testbed has been used to analyze software-defined communication solutions using cognitive radios in underground settings. This testbed has been utilized to develop advanced underground communication techniques during this project.

**Wayne Woldt**, Associate Professor, UNL Biological Systems Engineering, for the project: *Improving Variable Rate Irrigation Efficiency using a Real-time Soil Moisture Adaptive Control Model Informed by Sensors Deployed on Unmanned Aircraft*.

Masters Student: **Mitch Maguire**, for an M.S. in Biological Systems Engineering (funding awarded in 2015, student brought on board in 2016)



Variance in project plan: One of the variances the project team encountered is the use of a dual sensor system, rather than a triple sensor system. We experimented with the multi-spectral sensor and were able to combine the red, green and blue bands to achieve an adequate representation of an optical image. Thus, the team was able to eliminate the optical sensor and the associated weight and space requirements in the payload area of the aircraft. Another variance was a modification to the FAA issued Certificate of Authorization that extends the ceiling, or maximum altitude, of the unmanned aircraft from a height of 400 feet AGL up to 1199 feet AGL. This allows the project team to fly missions quicker and also aids synthesis of the images.

#### Presentations:

- Mitch Maguire, *Improving Variable Rate Irrigation Efficiency Using a Real-time Soil Moisture Adaptive Control Model Informed by Sensors Deployed on Unmanned Aircraft*, Water for Food Research Forum, April 26, 2018.
- Mitch Maguire, Burdette Barker, Christopher Neale, Wayne Woldt, *Modeling Evapotranspiration using Multispectral and Thermal Infrared Imagery Acquired with a Low Altitude Unmanned Aerial System*, 2018 Remote Sensing and Hydrology Symposium

- Mitch Maguire, Burdette Barker, Christopher Neale, Wayne Woldt, Andy Suyker, *Modeling Evapotranspiration using Multispectral and Thermal Infrared Imagery Acquired with a Low Altitude Unmanned Aerial System*, 2018 ASABE Annual International Conference
- Wayne Woldt, Christopher Neale, Derek Heeren, Eric Frew, George Meyer, *Improving Agricultural Water Efficiency with Unmanned Aircraft*, 2018 AUVSI Xponential Unmanned Aircraft Conference
- Mitch Maguire, Wayne Woldt, Christopher Neale, *A Production Field Scale Review of Agricultural Image Processing and Dual Sensor Integration for Unmanned Aircraft Systems (poster)*, 2017 DWFI Water for Food Global Conference
- Mitch Maguire, *Improving Variable Rate Irrigation Efficiency Using a Real-time Soil Moisture Adaptive Control Model Informed by Sensors Deployed on Unmanned Aircraft*, DWFI Research Forum, Lincoln, NE, May 11, 2017.
- Mitch Maguire, Wayne Woldt, Christopher Neale, George Meyer, Eric Frew, *A Survey of Agricultural Image Processing for Unmanned Aircraft Systems (paper)*, 2017 ASABE Annual International Conference
- Mitch Maguire, Wayne Woldt, Jacob Smith, Jack Elston, Eric Frew, *Thermal and Multi-Spectral Dual Sensor Integration for Unmanned Aircraft Systems (paper)*, 2017 ASABE Annual International Conference

#### Publications

- THESIS: Maguire, Mitch. An Evaluation of Unmanned Aerial System Multispectral and Thermal Infrared Data as Information for Agricultural Crop and Irrigation Management. (2018). ETD collection for University of Nebraska - Lincoln.  
<https://digitalcommons.unl.edu/biosysengdiss/82/>.

Changes in Knowledge/Action: Mitch Maguire earned his Master's degree in August 2018 and is continuing his research to earn his Ph.D. degree, based on the support of a USDA grant (briefly described below).

As part of this project, an Extension workshop entitled "*Flight to Maps*" was developed and delivered in which participants learned about unmanned aircraft, auto-pilot systems, sensors, and data processing. The workshop was delivered at the UNL Eastern Nebraska Research and Extension Center on April 23, 2018, with 15 participants spanning 5 states. This student support was critical in securing a USDA AFRI grant of nearly \$500,000 based on the research that has been pursued under this project. Now this research may be expanded in very significant directions.

- **Haishun Yang**, Associate Professor and Crop Simulation Modeler, UNL Agronomy and Horticulture, for the project: *Determination of field sensor density for real-time crop management*.  
Masters Student: **Babak Samani**, for an M.S. from UNL Computer Science & Engineering



#### Presentations:

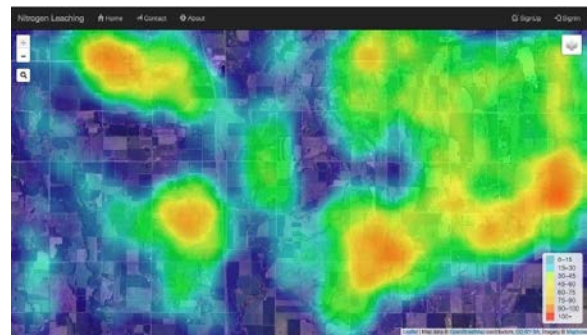
- Samani, Saeideh; Samani, Babak; and Yang, Haishun, "A Web Based Real Time Nitrogen Leaching Calculator" (2017). Poster Presented at University of Nebraska-Lincoln Research Fair, April 4-5, 2017.  
<http://digitalcommons.unl.edu/agronhortdiss/123>.
- DWFI Research Forum, Lincoln, NE, May 12, 2016. "Determination of Field Sensor Density for Real-time Crop Management."

Change in Knowledge/Action: **Babak Samani** graduated in 2017 and has gone on to work as a Software Development Engineer in the NASA Jet Propulsion Laboratory.

In this project, we designed and developed a new visualization system to display the risk of nitrogen leaching in corn fields in the state of Nebraska – Maize-N

(<https://hybridmaize.unl.edu/Maize-N>).

This system is accessible from anywhere by most mobile devices on any platform. The system takes three sets of data, including weather data, soil texture data, and field data, and computes the risk of N leaching and visualize this risk to the users. Users, especially producers and researchers, can explore and discover the risk of N leaching for different locations in different styles such as heat-map and colored polygons. We integrated heterogeneous datasets into the system to help producers and domain scientists establish the connection between different input parameters of the system which cause different amount of nitrogen leaching. Several experiments with real-world weather data and user inputs demonstrate the effectiveness of the system. To give this confidence to users to use the application, we applied several levels of security to the system. In addition, to maximize the performance of the application, several back-end services have been applied to the system.



*Nitrogen leaching web application*



## Round Three

In 2016 eleven awards were given to support graduate student research. Faculty Fellows secured additional funds on their own to support the students, matching DWFI funds one-to-one. **By FY19 support continues for six of the eleven students originally awarded support.**

### Daugherty Graduate Research Assistantships – MS and Ph.D. positions

DWFI Faculty Fellows were invited to submit applications for student support up to \$16,500, with additional student funding secured by the Faculty Fellow. Student support was awarded to:

- **P. Stephen Baenziger**, Professor, UNL Agronomy and Horticulture, for the project: *Agronomic and Genomic Evaluation of Winter Wheat for Hybrid Seed Breeding*.  
Ph.D. Student: **Amanda Easterly**, for a Ph.D. in Agronomy (Plant Breeding and Genetics Emphasis)



#### Presentations:

- International Annual Meeting of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Phoenix, Arizona, November 2016.
- International Wheat Yield Partnership Grant Meeting at the Plant and Animal Genome Conference, January 2017.
- Water for Food Global Conference, April 2017.
- UNL Spring Research Fair, April 2017.
- Conference for Applied Statistics in Agriculture, Manhattan, KS, April 2017.
- DWFI Research Forum, May 11, 2017.

#### Publications:

- Waseem Hussain, P. Stephen Baenziger, Vikas Belamkar, Mary J. Guttieri, Jorge P. Venegas, Amanda Easterly, Ahmed Sallam, and Jesse Poland. Genotyping-by-Sequencing Derived High-Density Linkage Map and its Application to QTL Mapping of Flag Leaf Traits in Bread Wheat. (2017) *Scientific Reports*, 7: 16394. DOI:10.1038/s41598-017-16006-z.
- DISSERTATION: Easterly, Amanda Christine, "Developing Hybrid Wheat for the Great Plains: Addressing Hybridization, Heterosis, and Heterotic Pool Development" (2017). ETD collection for University of Nebraska - Lincoln. AAI10682750. <https://digitalcommons.unl.edu/dissertations/AAI10682750>.

Changes in Knowledge/Action: **Amanda Easterly** successfully defended her thesis and earned her Ph.D. December 2018. She is the first student to graduate from the hybrid wheat program. She is currently a Research Assistant Professor in Agronomy & Horticulture and a UNL Extension specialist in Sidney, NE. A list of her extension publications is available [here](#).

Steve Baenziger submitted a proposal for another graduate student who was awarded funding in Round Four. For associated information, see Round Four – Nicholas Garst.

- **Guillermo Baigorria**, Assistant Professor, UNL School of Natural Resources and Agronomy and Horticulture, for the project: *Climate change impacts assessment on water requirements and yields on corn, soybean and wheat in the USA*.

Ph.D. Student: **Amit Timilsina**, for a Ph.D. in Natural Resource Sciences (specializing in Climate Assessment and Impacts)

Data and software provided by Next Season Systems LLC. Data and software were provided under a non-profit agreement for the exclusive use of Amit's thesis research.

#### Presentations:

- Water for Food Global Conference, April 2017 (poster)
- DWFI Research Forum, May 11, 2017

#### Publications:

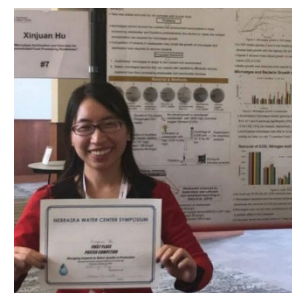
- THESIS: Timilsina, Amit Prasad, "Assessment of Climate Change Impacts on Major Crops in the United States of America" (2017). *ETD collection for University of Nebraska - Lincoln*. AAI10607308. <https://digitalcommons.unl.edu/dissertations/AAI10607308>

Changes in Knowledge/Action: Amit Timilsina earned his Ph.D. and graduated August 2017. The information generated has a lot of value in terms of projecting crop yield, water requirements and water efficiency in two of the most economically important crops in the USA – corn and soybean. By knowing the projected water requirement under climate change at high resolution, we can plan for how many more years we can continue applying irrigation from groundwater sources, to be able to plan a better use of water in the future, and to begin testing different adaptation practices such as changing planting dates, use of new varieties, or even changing to more water efficient crops in certain regions.

- **Yulie Meneses**, Research Assistant Professor, and **Jayne Stratton**, Research Associate Professor, UNL Food Science and Technology, for the project: *Reconditioning and reuse of processing wastewater. An application for the grain wet milling industry*  
Ph.D. Student: **Xinjuan Hu**, for a Ph.D. in Food Science and Technology

Meat processing consumes approximately 62 million m<sup>3</sup> of fresh water/year worldwide and has been listed as the top water consumer in food and beverage industry (Bustillo-Lecompte and Mehrvar, 2015; de Sena et al., 2009). At the end of meat processing about 89% of the fresh water becomes highly polluted wastewater with considerably higher concentrations of organic pollutants, especially nitrogen and phosphorus, than municipal influent. Microalgae, which is a type of photosynthetic aquatic microorganism, has been reported to be able to efficiently remove nitrogen and phosphorus, heavy metals from wastewater produced by industry, agriculture and municipal. To date organic pollutants in meat processing wastewater were efficiently removed and transferred into valuable products using “beads” with microalgae immobilized in alginate gel. The alginate beads have been evaluated to find the:

1. optimum ratio of alginate gel to microalgae in the treatment material (microalgae “beads”)
2. Impact of environmental temperature on microalgae growth and pollutant removal



#### Presentations:

- 2019 Water for Food Global Conference
- 2019 Scientific Research Fair of UNL
- 2018 Institute of Food Technology,
- DWFI Research Forums: May 11, 2017; April 26, 2018

#### Publications:

- Xinjuan Hu, Yulie E. Meneses, Jayne Stratton, Bing Wang. "Acclimation of consortium of micro-algae help removal of organic pollutants from meat processing wastewater." *Journal of Cleaner Production* 214 (2019): 95-102.



*Alginate "beads" containing microalgae suspended in gel, used to treat wastewater*

<https://doi.org/10.1016/j.jclepro.2018.12.255>.

- Yulie E. Meneses, Bismarck Martinez, Xinjuan Hu. Chapter 13: Water Reconditioning in the Food Industry. *Sustainable Water and Wastewater Processing*. In press. eBook ISBN: 9780128161715.

Changes in Knowledge/Action: **Xinjuan Hu** is continuing her PhD research in Food Science at UNL, with an expected graduation date of 2020.

The final purpose of this project was to treat high strength meat processing wastewater to reach the standard of discharge and obtain microalgae biomass for lipid extraction. Currently, a microalgae consortium (*S. obliquus*, *C. vulgaris*, *C. sorokiniana*) being able to well adapt to the harsh environment in meat processing wastewater and showing robust growth has been selected. With this microalgae consortium, levels of TP- PO<sub>4</sub><sup>3-</sup>, TN and COD in wastewater could reach as low as 12.0 mg/L, 45.4 mg/L, and 604 mg/L. In order to make the microalgae-based wastewater treatment applicable at large scale, an immobilized system has been studied and developed successfully following previous study. In the next step the environmental impact and cost analysis of this system will be evaluated and compared with conventional wastewater treatment technology.

- **Cory Forbes**, Associate Professor, UNL School of Natural Resources, and Coordinator, Science Literacy Initiative, for the project: *Fostering Undergraduate Students' Disciplinary Learning and Water Literacy*. Ph.D. Student: **Destini Petitt**, for an M.S. in Natural Resource Sciences with an emphasis on Science Literacy



#### Presentations:

- **Petitt, D.**, Lally, D., Forbes, C.T., Brozovic, N., & Franz, T. *Transdisciplinary Undergraduate Students' Learning and Reasoning about Socio-hydrological Issues*. Poster accepted to the 2018 Earth Educators Rendezvous Meeting (EER), Lawrence, KS.
- **Petitt, D.** *A comparative study of the role of values in reasoning about socio-hydrological issues in undergraduate students from developed and developing countries*. Research presented at the 2018 Daugherty Water for Food Institute (DWFI) research forum, Lincoln, NE.
- **Petitt, D.**, Lally, D., Forbes, C.T., Brozovic, N., & Franz, T. *Transdisciplinary Undergraduate Students' Learning and Reasoning about Socio-hydrological Issues*. Poster presented at the 2018 meeting of the National Association of Research in Science Teaching (NARST), Atlanta, GA.
- **Petitt, D.**, Lally, D., Forbes, C.T., Brozovic, N., & Franz, T. *Transdisciplinary Undergraduate Students' Learning and Reasoning about Socio-hydrological Issues*. Poster presented at the 2017 meeting of the Geological Society of America Conference (GSA), Seattle, WA.
- Lally, D., **Petitt, D.**, Forbes, C.T., Brozović, N., & Franz, T. *Water in Society: Interdisciplinary Undergraduate Teaching and Learning about Water*. Research presented at the 2017 meeting of the Earth Educators Rendezvous, Albuquerque, NM.
- Forbes, C.T., Brozović, N., Franz, T., Lally, D., & **Petitt, D.** *Transdisciplinary Undergraduate Water Education: Pedagogical Reflections*. Research presented at the 2017 meeting of the North American Colleges and Teachers of Agriculture Conference (NACTA), Purdue University, West Lafayette, IN.
- **Petitt, D.** *A comparative study of the role of values in reasoning about socio-hydrological issues in undergraduate students from developed and developing countries*. Research presented at the 2017 Daugherty Water for Food Institute (DWFI) research forum, Lincoln, NE.
- Forbes, C.T., Brozović, N., Franz, T., Lally, D., & **Petitt, D.** *Fostering undergraduate students' disciplinary learning and science literacy*. Poster presented at the 2017 meeting of the Water for Food Global Conference, Lincoln, NE.
- Forbes, C.T., Brozović, N., Franz, T., Lally, D., & **Petitt, D.** *Fostering undergraduate students' disciplinary learning and science literacy*. Poster presented at the 2016 meeting of the Geological Society of America (GSA), Denver, CO.
- Forbes, C.T., Brozović, N., Franz, T., Lally, D., & **Petitt, D.** *Fostering undergraduate students' disciplinary learning and science literacy*. Poster presented at the 2016 meeting of the Nebraska Water Center Symposium and Water Law Conference, Lincoln, NE.
- Forbes, C.T., Brozović, N., Franz, T., Lally, D., & **Petitt, D.** *Fostering undergraduate students' disciplinary learning and science literacy*. Poster presented at the 2016 meeting of the STEM Education Retreat, Lincoln, NE.

#### Publications:

- Forbes, C.T., Brozović, N., Franz, T., Lally, D., & **Petitt, D.** "Water in Society: An Interdisciplinary Course to Support Undergraduate Students' Water Literacy". Article accepted to the Journal of College Science Teaching (JCST) 2017.
- THESIS: Petitt, D. (2018). A Comparative Study of the Role of Values in Reasoning about Socio-hydrological Issues in Undergraduate Students from Developed and Developing Countries. Masters Thesis, University of Nebraska, Lincoln, Nebraska.  
<https://digitalcommons.unl.edu/natresdiss/172/>.

#### Results and assessment of projects from inception to date

- Research in *SCIL 101 "Water and Decision-making for a complex world"* – Completed
  - This class was designed to help students become scientifically-informed decision-makers. While the class focused on various socio-scientific issues, Destini's research in this class focused on how students use their values in reasoning about complex socio-hydrological issues.

Changes in Knowledge/Action: **Destini Petitt** graduated in the Spring of 2018. She is currently working as a Research Assistant at the University of North Carolina (Aug 2018 – present). The project has served over 100 students from both STEM and non-STEM departments

- **Trenton Franz**, Associate Professor of Hydrogeophysics, UNL School of Natural Resources, for the project: *Observed and modeled quantification of reduced pumping volumes using advanced irrigation technologies in Western Nebraska*.  
Ph.D. Student: **Justin Gibson**, for a Ph.D. in Natural Resource Sciences (specializing in Bio-Atmospheric Interactions)



Justin's work focused in western Nebraska where a cost-share program facilitated by Coca-Cola and the Nature Conservancy has been underway since 2014. The purpose of this cost-share is to quantify water savings that can be achieved by utilizing advanced technology to schedule irrigation, including: prescription mapping of fields, variable speed irrigation, and soil moisture probes. In terms of research, Justin has been instrumental in gathering producer management data by working with the local NRD, implementing a soil physics laboratory, performing geophysical surveys within the study site, utilizing remote sensing analyses for case study investigations, and completing numerous crop modeling scenarios. Results from this ongoing research will be used to influence more wide-spread adoption of water-saving technology to improve agricultural water use.

#### Presentations:

- WaterSmart Innovations in Las Vegas, NV
- Global Forum for Innovations in Agriculture in Abu Dhabi, UAE
- MOISST in Lincoln, NE
- International Water Security Conference in Toronto, Ontario
- Water for Food Research Forum (poster), April 26, 2018
- 2017 Water for Food Global Conference



#### Publications:

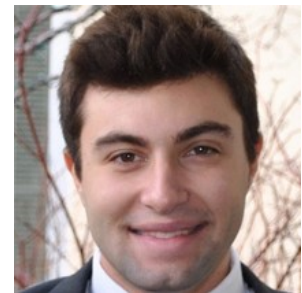
- Gibson, J., Franz, T.E. (2018) Spatial prediction of near surface soil water retention functions using hydrogeophysics and empirical orthogonal functions. J. Hydrol. 561, 372-383. <https://doi.org/10.1016/j.jhydrol.2018.03.046>.
- Finkenbiner, Catherine E.; Franz, Trenton E.; Gibson, Justin P.; Heeren, Derek M.; and Luck, J. D., "Integration of hydrogeophysical datasets and empirical orthogonal functions for improved irrigation water management" (2018). Biological Systems Engineering: Papers and Publications. 552. <http://dx.doi.org/10.1007/s11119-018-9582-5>.
- Gibson, J., Franz, T. E., Wang, T., Gates, J., Grassini, P., Yang, H., and Eisenhauer, D. (2017) A case study of field-scale maize irrigation patterns in western Nebraska: implications for water managers and recommendations for hyper-resolution land surface modeling, Hydrol. Earth Syst. Sci., 21, 1051-1062. <https://doi.org/10.5194/hess-21-1051-2017>.
- Foolad, F., Franz, T. E., Wang, T., Gibson, J., Kilic, A., Allen, R. G., and Suyker, A. (2017) Feasibility analysis of using inverse modeling for estimating field-scale evapotranspiration in maize and soybean fields from soil water content monitoring networks, Hydrol. Earth Syst. Sci., 21, 1263-1277. <https://doi.org/10.5194/hess-21-1263-2017>.
- DISSERTATION: Gibson, Justin Philip, "Groundwater Recharge Response to Reduced Irrigation Pumping in Western Nebraska" (2018). ETD collection for University of Nebraska - Lincoln. AAI10981436. [digitalcommons.unl.edu/dissertations/AAI10981436](https://digitalcommons.unl.edu/dissertations/AAI10981436).

Changes in Knowledge/Action: **Justin Gibson** graduated with his Ph.D. in Natural Resource Sciences in December 2018. He continued on to become a Post-Doctoral Research Associate at DWFI for six months, before joining CropMetrics, a Nebraska ag-tech start-up company, as a Data Scientist. Additionally, this project established working relationships with numerous producers and the local Natural Resources District. These study sites will serve as key infrastructure for Professor Franz's lab activities over the next several years.

- **Troy Gilmore**, Assistant Professor of Groundwater Hydrology, UNL School of Natural Resources, for the project: *Streambed water flux dynamics at coupled groundwater-surface water monitoring stations*. Masters Student: **Mason Johnson**, for an M.S. in Natural Resource Sciences and **Martin Wells**, for an M.S. in Biological Systems Engineering

DWFI support has provided training opportunities for two graduate students, Mason Johnson and Marty Wells, to conduct groundwater discharge measurements in streams and streambeds. Mason Johnson has conducted an extensive literature review and developed an MS thesis proposal centered on the project as originally proposed, focusing on distributed temperature sensing (DTS). Key outcomes include: 1) Two proposed field campaigns completed; 2) Continued collaboration with participants and partners; 3) Manuscript/thesis chapter based on first field campaign in preparation.

Though temperature data collection from the second field campaign was successful, a robust comparison of physical discharge measurements at informed and uninformed locations was not possible. However, results will be published in Mason's thesis, with a focus on comparing and improving FO-DTS application under two very different field conditions in this study.



Mason Johnson

Presentations: DWFI Research Forum, May 11, 2017; Water for Food Research Forum (poster), April 26, 2018.

Publications:

- Gilmore, T., Zlotnik, V., Johnson, M. (2018). Recognition of regional water table patterns for estimating groundwater recharge rates. *Groundwater*.
- Wells, Martin J.; Gilmore, Troy E.; Mittelstet, Aaron R.; Snow, Daniel D.; and Sibray, Steven S., "Assessing Decadal Trends of a Nitrate Contaminated Shallow Aquifer in Western Nebraska Using Groundwater Isotopes, Age-Dating, and Monitoring" (2018). *Water*, 10: 1047. <https://doi.org/10.3390/w10081047>.
- THESIS: Wells, Martin. Assessing the Relationship Between Groundwater Nitrate Concentrations and Environmental Variables Through Repeat Sampling and Statistical Machine Learning: Dutch Flats, Nebraska. (2018) ETD collection for University of Nebraska - Lincoln. <https://digitalcommons.unl.edu/embargotheses/137/>.

Changes in Knowledge/Action: **Mason Johnson** graduated with his M.S. in Hydrology in 2018. He currently works as a Graduate Research Assistant at UNL and as a Student Trainee in Hydrology at the U.S. Geologic Survey.

The students have benefited significantly, engaging in conversations with leading experts on DTS. Overall the project is on schedule and will lead to scientific advancement in groundwater discharge measurement techniques. As planned, the project will also increase understanding of groundwater discharge patterns in the Sandhills and in the Elkhorn River, which is critical information for Nebraska stakeholders and water resources managers.

- **Christopher Gustafson**, Associate Professor, UNL Agricultural Economics, for the project: *Behaviors to Mitigate the Risk of Waterborne Illness: An Analysis of Pastoralist Households in Rural Tanzania*.  
Ph.D. Student: **Mazbahul Ahamad**, for a Ph.D. in Natural Resource Sciences

The overarching goal of the dissertation research project was to analyze households' water, sanitation, and hygiene (WASH)-related health behaviors based on longitudinal data for a sample of 196 pastoralist households from a four-year study in rural Tanzania. The second aim was to study the impact of a concise educational intervention delivered to households about WASH behaviors, which occurred between the surveys implemented in years 2 and 3 of the four-year project. The project has resulted in the analysis of a four-year panel dataset of WASH behaviors, water sources, and an education intervention that promoted the adoption of health-promoting behaviors related to water from 196 pastoralist households in Pawaga and Idodi divisions in Iringa region, Tanzania.



Presentations:

- 2018 Sustainability and Development Conference, hosted by the University of Michigan's Sustainability and Development Initiative

- Ex-post Livestock Diseases, and Pastoralists' Averting Decisions in Tanzania, Agricultural and Applied Economics Association Annual Meetings, August 2016, Tanzania (with C. Gustafson and E. Van Wormer)
- DWFI Global Conference, April 2019
- DWFI Research Forum, April 26, 2018
- DWFI Research Forum, May 11, 2017

Publications:

- Pastoralists' water, sanitation, and hygiene (WASH)-related preventive health behaviors in Tanzania

Changes in Knowledge/Action: Fourteen percent (14%) of pastoralists treated water before receiving preventive health education; the percentage treating water increases to twenty seven percent (27%) after receiving the health education. This is a statistically significant increase of 89% in water treatment following health education.

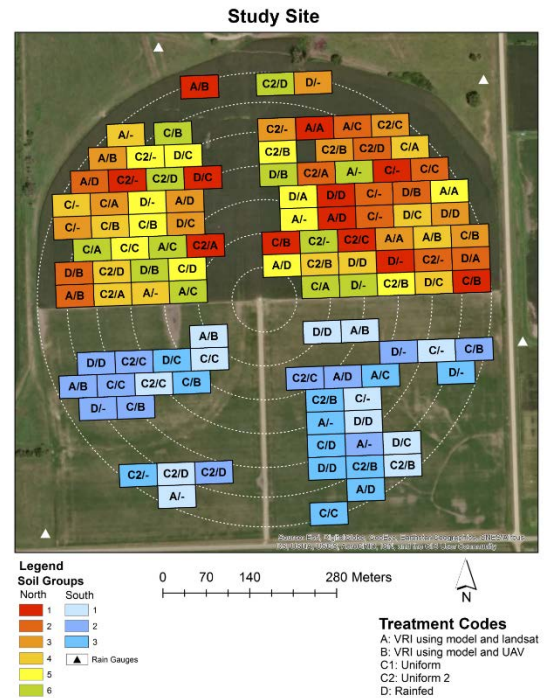
The project has helped us identify a number of gaps in the literature about water availability, selection, and preventive health behaviors. These gaps present excellent opportunities for future research that will contribute meaningfully to our understanding of preventive health behaviors related to water use and WASH more generally in resource-poor environments and ways to most effectively design and target educational interventions to promote healthier behaviors.

- [Derek Heeren](#), Associate Professor of Irrigation Engineering, UNL Biological Systems Engineering, for the project: Field Testing Variable Rate Irrigation (VRI) for Managing Spatial Variability in Soils and Evapotranspiration.  
Masters Student: **Sandeep Bhatti**, for an M.S. in Biological Systems Engineering, who began his program in January 2017.



The objectives of this project were to utilize field experiments to evaluate variable rate irrigation (VRI) for adapting irrigation to spatial water holding capacity and spatial evapotranspiration. VRI was evaluated for benefits in terms of reduced pumpage and increased yield potential compared to conventional irrigation methods at a commercial field scale. A secondary objective is to develop best management practices for utilizing VRI to achieve these benefits. This research is building on the research of Himmy Lo and Burdette Barker, both of whom have also received support from DWFI.

The specific activities included data collection from the field site weekly throughout the 2017 and 2018 growing season, applying real-time irrigation through operation of center pivot irrigation systems and modeling crop water requirements through a remote sensing-based water balance model on weekly basis. SETMI is a remote sensing-based model, which is used to compute spatial evapotranspiration in agricultural fields. SETMI has capabilities of creating VRI prescriptions and forecasting the irrigation needs. SETMI takes inputs of multispectral and thermal imagery from satellite and unmanned aerial systems (UAS), soils map, daily weather data, previous prescription maps, and soil water content measurements. SETMI was run on weekly basis to compute irrigation requirements over the field and develop VRI prescription maps.



*VRI Treatment Map*

#### Presentations:

- Bhatti, S., A. Kumari, A. Sarangi, R. Kaur, D. M. Heeren, M. Singh, C. M. U. Neale, and D. L. Martin. July 7-10, 2019. Integrated soil moisture and canopy temperature sensing system for irrigation scheduling. ASABE Annual International Meeting, Boston, Mass. Oral presentation.
- Bhatti, S., A. Kumari, A. Sarangi, R. Kaur, D. M. Heeren, M. Singh, C. M. U. Neale, and D. L. Martin. April 29-30, 2019. Integrated soil moisture and canopy temperature sensing system for irrigation scheduling. DWFI Water for Food Global Conference, Lincoln, Nebr. Poster presentation.
- Heeren, D. M., J. B. Barker, S. Bhatti, D. R. Rudnick, and F. Munoz-Arriola. February 26-27, 2019. Impact of variable rate irrigation (VRI) on consumptive use of water resources. Central Plains Irrigation Association (CPIA) Central Plains Irrigation Conference, Kearney, Nebr. Invited presentation.
- DWFI Water for Food Conference 2017, 2019 (poster)
- Water for Food Research Forum, 2017, 2018, 2019
- Nebraska Water Center Symposium, 2017 (2<sup>nd</sup> place poster), 2018

#### Publications:

- Paper submitted to *Agricultural Water Management*. (2019)
- Barker, J. B., S. Bhatti, D. M. Heeren, C. M. U. Neale, and D. R. Rudnick. (2019) Variable rate irrigation of maize and soybean in West-Central Nebraska under full and deficit irrigation. *Frontiers in Big Data* 2(34). <https://doi.org/10.3389/fdata.2019.00034>.
- THESIS: Bhatti, S. (2018). Variable Rate Irrigation Using a Spatial Evapotranspiration Model With Remote Sensing Imagery and Soil Water Content Measurements. MS Thesis. University of Nebraska-Lincoln. <https://digitalcommons.unl.edu/biosysengdiss/83/>.

Changes in Knowledge/Action: **Sandeep Bhatti** graduated in December 2018, and continued on to a Ph.D. degree with Dr. Heeren. He currently works as a Graduate Research Assistant. To read more about Sandeep's work, see project "*Sensor-Based Irrigation Management for Maize and Soybean in the Great Plains*."

The DWFI funding was used to leverage funding from a USDA grant to build a large research team to address multiple dimensions of this topic. This research has demonstrated the importance of incorporating soil water measurements into VRI management. Barker et al., 2018 found that VRI management using SETMI without incorporation of soil water measurements prescribed significantly larger depth of water or over irrigated the plots compared to other methods. In this research, the incorporation of soil water in SETMI reduced the prescribed irrigation depth.

- **Alan Kolok**, Director, Center for Environmental Health and Toxicology, UNMC College of Public Health, and Professor, UNO Biology, for a project to study the pressure that agrichemicals exert on water resources.

Ph.D. Student: **Jonathan Ali**, for a Ph.D. from the UNMC College of Public Health

(Note: student initially awarded during Round One; subsequently funded as part of Round Three, match required)

Since the start of his support from DWFI in 2014, Ali has advanced multiple projects on behalf of the University of Nebraska both in Nebraska and abroad. All of these projects, along with his dissertation research, are focused on assessing the impacts of agricultural runoff on freshwater resources and public health both locally in Nebraska and abroad. These on-going projects were a part of the proposal for support submitted in May 2015 and include: investigate the persistence of adverse biological impacts from agricultural runoff on adult and early life stages of the environmental sentinel organism, the fathead minnow; continue on-going research on the integration of biomonitoring and citizen science for detection of agricultural runoff in Chilean watersheds; explore the use of citizen science to simultaneously monitor for agricultural contaminants and promote environmental stewardship in rural and urban watersheds.

Based on these proposed objectives, Ali has published one first author manuscript (Ali et al. 2017) and coauthored two additional manuscripts (Sangster et al. 2016; Schulze et al. 2016), with an additional three manuscripts in preparation for publication. This work has focused on the use of environmental sentinels (fish) to understand the adverse health impacts from

exposure to agricultural runoff in freshwater systems. Between May 1st and June 9th, 2017, Ali was scheduled to give three presentations at national conferences on his dissertation research evaluating the compensatory mechanisms for early life exposure to agricultural runoff. In this award cycle alone, Ali has given three presentations and produced five posters presented at numerous regional and national scientific conferences and workshops (see below).

Internationally, Ali has continued work on developing methods to apply molecular tools for monitoring agricultural pollution through an on-going collaboration between his advisor Alan Kolok, Ph.D., and Nicolas Gouin, Ph.D., of the University of La Serena. Through this collaboration, Ali has also taken an undergraduate mentee, Luke Allmon, to Chile for sampling of pesticides in the waters and sediments of the agriculturally intensive Choapa River Basin. This project has produced one peer-reviewed manuscript with an additional manuscript currently in preparation that are of interest to our collaborators and other biologists and environmental scientists throughout Chile.

Outside of his rigorous laboratory and field research, Jonathan has continued to participate in community outreach and education related to water resources and public health. This has included outreach events with the Nebraska Watershed Network, as well as serving as a capstone mentor for students enrolled in the Urban Agriculture & Food Science Career Academy at Bryan High School, Omaha.

#### Presentations:

- **Ali J.M.**, Kolok A.S. and S.L. Bartelt-Hunt. (Invited) Assessing Agricultural Runoff in the Elkhorn River Watershed and Beyond: Lessons Learned and Future Directions. Indo-US Workshop on Addressing the Nexus of Food, Energy, and Water (FEW) in the Context of Societal Challenges. National Science Foundation and Indo-US Science Technology Forum. Indian Institute of Technology, Bengaluru, India. Apr 2017.
- **Ali J.M.**, Schulze T., Gouin N., Davis P.H. and A.S. Kolok. Development of a native pencil catfish (*Trichomycterus areolatus*) as a freshwater environmental sentinel of pollution in Chile. 7th Society of Environmental Toxicology and Chemistry (SETAC) World Congress/SETAC North America 37th Annual Meeting Orlando, FL, USA. Nov 2016.
- **Ali J.M.**, Schulze T., Gouin N., Davis P.H. and A.S. Kolok. Molecular Tools for Water Quality Monitoring: Development of a Native Sentinel Organism in Chile. College of Public Health Global Health Fellows 2015 Seminar, UNMC, Omaha, NE, USA. Oct 2016.
- **Ali J.M.** and A.S. Kolok. (Invited) Biomonitoring Watersheds in Nebraska and Chile: Advancing toxicity studies of agricultural runoff both near and far. Robert B. Daugherty Water for Food Institute 2016 Research Forum, University of Nebraska Lincoln, NE, USA. May 2016.
- **Ali J.M.**, Farhat Y.A. and A.S. Kolok. Exposure of fathead minnow larvae to an agrichemical pulse: altered gene expression in the field. Nebraska Chapter of the American Fisheries Society Meeting-Streams and Rivers Technical Meeting, Gretna, NE, USA. Dec 2015.
- **Ali J.M.**, Farhat Y.A. and A.S. Kolok. Altered aromatase expression in fathead minnow larvae following in situ exposure to an agrichemical pulse. Society of Environmental Toxicology and Chemistry 2015 North America 36th Annual Meeting, Salt Lake City, UT, USA. Nov 2015.



- **Ali J.M.** and A.S. Kolok. (Invited) Novel assessment tools: Utilizing citizen science and sentinel organisms to detect agrichemical runoff. Robert B. Daugherty Water for Food Institute 2015 Research Forum, University of Nebraska Lincoln, NE, USA. May 2015.

#### Poster Presentations:

- **Ali J.M.**, D'Souza D.L., Singh R.P., Bartelt-Hunt S.L. and A.S. Kolok. Endocrine challenges of a Midwest upbringing: Investigating the impacts of agricultural runoff on larval fish following in situ and laboratory exposures. 2017 Water for Food Global Conference. Lincoln, NE, USA. Apr 2017. (**2<sup>nd</sup> Place Onsite Poster Competition**)
- **Ali J.M.**, Schulze T., Gouin N., Davis P.H. and A.S. Kolok. Development of a native pencil catfish (*Trichomycterus areolatus*) as an environmental sentinel for freshwater pollution in Chile. 3rd Annual Global Health Conference Midwest "Empowering Agents of Change Across Our World". Omaha, NE, USA. Feb 2017. (**Best Research Poster Award**)
- Kolok A.S. and **Ali J.M.** Too thick to drink, too thin to plow: Chemical mixtures in the Elkhorn River, Nebraska. 7th SETAC World Congress/SETAC North America 37th Annual Meeting. Orlando, FL, USA. Nov 2016.
- **Ali J.M.**, Schulze T., Kumar S., Gouin N., Davis P.H. and A.S. Kolok. Biomonitoring and Surveillance of Pesticides in the Agriculturally-Dominated Choapa River, Coquimbo, Chile. 2016 Water for Food Global Conference. Lincoln, NE, USA. Apr 2016.
- **Ali J.M.**, Rakestraw M.J., Herrmann K.M.K. and A.S. Kolok. Pesticide runoff in Midwestern Watersheds: Can citizen science help collect the data scientists need? University of Nebraska at Omaha Sustainability Launchpad: Water. Omaha, NE, USA. Apr 2016. (**1<sup>st</sup> Place Student Poster Competition**)
- **Ali J.M.**, Banan A. and A.S. Kolok. Chronic Effects of Silver Nanoparticles on Fingerling Persian Sturgeon (*Acipenser persicus*). Society of Environmental Toxicology and Chemistry 2015 North America 36th Annual Meeting. Salt Lake City, UT, USA. Nov 2015.
- Kolok A.S., Zhang Y., Krysl R., **Ali J.M.** and S.L. Bartelt-Hunt. Muddy Waters: The role of sediment in CEC fate, transport and bioavailability. Society of Environmental Toxicology and Chemistry 2015 North America 36th Annual Meeting. Salt Lake City, UT, USA. Nov 2015.
- Rakestraw M.J., Herrmann K.M.K., **Ali J.M.** and A.S. Kolok. Pesticides in surface water: Can citizen science help collect the data scientists need? Society of Environmental Toxicology and Chemistry 2015 North America 36th Annual Meeting. Salt Lake City, UT, USA. Nov 2015.
- **Ali J.M.**, Farhat Y.A. and A.S. Kolok. Altered aromatase expression in fathead minnow larvae following in situ exposure to an agrichemical pulse. Nebraska Environmental Health Association 2015 Meeting, Ashland, NE, USA. Oct 2015.
- Rakestraw M.J., Herrmann K.M.K., **Ali J.M.** and A.S. Kolok. Pesticides in surface water: Can citizen science help collect the data scientists need? Nebraska Environmental Health Association 2015 Meeting, Ashland, NE, USA. Oct 2015.
- Zhang Y., Krysl R.G., **Ali J.M.**, Snow D.D., Kolok A.S. and S.L. Bartelt-Hunt. Impact of Sediment on Agrichemical Fate and Bioavailability to Aquatic Organisms. Association of Environmental Engineering and Science Professors 2015 Research and Education Conference. New Haven, CT, USA. Jun 2015.
- **Ali J.M.** and A.S. Kolok. Pesticide runoff in the Elkhorn River, Nebraska, USA: Temporal variation in chemical occurrence and biological impact. Society of Environmental Toxicology and Chemistry 2014 North America 35th Annual Meeting. Vancouver, BC, Canada. Nov 2014.

#### Publications:

- **Ali J.M.**, D'Souza D.L., Allmon L.G., Schwarz K.T., Singh R.P., Snow D.D., Bartelt-Hunt S.L. and A.S. Kolok. Biological Impacts Following Early Life Exposure to Water and Sediment Found in Spring Agricultural Runoff.
- **Ali J.M.**, Allmon L.G., Schulze T.T., Kallenbach A.T., Snow D.D., Davis P.H., Bertin A., Gouin N. and A.S. Kolok. Surveillance of anthropogenic stressors within a Chilean watershed utilizing a native environmental sentinel, *Trichomycterus areolatus*.
- **Ali J.M.**, Kallenbach A.T., Chavez E., Ramirez J., Onanong S., Snow D.D. and A.S. Kolok. Estrogenic impacts of early life exposure to a putative estrogen receptor antagonist, fulvestrant, in the fathead minnow.
- Knight L.A., **Ali J.M.**, D'Souza D.L., and A.S. Kolok. Exposure of two sentinel organisms, the northern leopard frog (*Lithobates pipiens*) and the fathead minnow (*Pimephales promelas*) to atrazine and a synthetic mixture of pesticides.
- **Ali J.M.**, Sangster J.L., Snow D.D., Bartelt-Hunt S.L. and A.S. Kolok. (2017) Compensatory response of fathead minnow larvae following a pulsed in-situ exposure to a seasonal agricultural runoff event. *Science of the Total Environment*, *in press*.
- Schulze T.T., **Ali J.M.**, Bartlett M.L., McFarland M.M., Clement E.J., Won H.I., Sanford A.G., Monzingo E.B., . . .Gouin N., Kolok A.S., and P.H. Davis. (2016) De novo Assembly and Analysis of the Chilean Pencil Catfish *Trichomycterus areolatus* Transcriptome. *Journal of Genomics*, 4, 29-41.
- Sangster J.L., **Ali J.M.**, Snow D.D., Kolok A.S. and S.L. Bartelt-Hunt. (2016). Bioavailability and fate of sediment-associated progesterone in aquatic systems. *Environmental Science and Technology*, 50(7), 4027–4036.
- **Ali J.M.**, Farhat Y.A., and Kolok, A.S. (2016). Biological impacts in fathead minnow larvae following a 7-day exposure to agricultural runoff: A microcosm study. *Bulletin of Environmental Contamination and Toxicology*, 96(4), 432-437.
- **Ali J.M.**, Herrmann, K.M.K., Rakestraw, M.J., and Kolok, A.S. (2016). Citizen-based scientific data collection: Fact or fiction? *Integrated Environmental Assessment and Management*, 12(2), 400-402.
- Zhang Y., Krysl R.G., **Ali J.M.**, Snow D.D., Kolok A.S. and S.L. Bartelt-Hunt. (2015) Impact of sediment on the fate and bioavailability of agrichemicals to adult female fathead minnows: a field study. *Environmental Science and Technology*, 49(15), 9037–9047.
- **Ali J.M.** and A.S. Kolok. (2015) On-site, serial exposure of female fathead minnows to the Elkhorn River, Nebraska, USA, spring agrichemical pulse. *Environmental Toxicology and Chemistry*, 34(6), 1354-1361.

#### Other Publications and Technical Reports (2)

- Krysl R.G., **Ali J.M.** and A.S. Kolok. (in review) Chapter 2: On-site exposure of fathead minnows (*Pimephales promelas*) in the Missisquoi River, VT, for indicators of endocrine disruption. U.S. Fish and Wildlife 2013-2014 Unit Report.
- **Ali J.M.**, Sellin Jeffries M.K. and A.S. Kolok. (2017) Uncharted Waters: Field Ecotoxicology in Remote Locations on Limited Resources. Society of Environmental Toxicology and Chemistry (SETAC) Globe: Session Summary. 18(1).

Changes in Knowledge/Action: Ali earned his Ph.D. in December 2017. He accepted a position as a toxicologist with the state of New Hampshire and began his new position in October 2018.

- **Aaron Mittelstet**, Assistant Professor, UNL Biological Systems Engineering, for the project: *Quantifying the Impact of Eastern Red Cedar Encroachment on Recharge in the Nebraska Sandhills*. Ph.D. Student: **Nawaraj Shreshtha & Yaser Kishawi**, for a Ph.D. in Natural Resource Sciences



Yaser Kishawi

Aaron Mittelstet submitted a proposal to Nebraska's Water Sustainability Fund, using the funds for this student support award as part of the matching requirement for his proposal. His proposal was funded, although not until a subsequent round.

Nawaraj Shreshtha joined the project in August 2018. He specializes in GIS and remote sensing. He has three objectives that will improve the modeling of the Nebraska Sandhills and will help us understand the impact of Red Cedar encroachment in the Nebraska Sandhills:

1. evaluate how climate impacts the thousands of lakes in the Sandhills;
2. quantify the current status of the Eastern Red Cedar within our study area; and
3. use the lakes as monitoring wells as the lakes are basically where the groundwater is above the surface. With a limited number of monitoring wells in our study area, the lakes can help us create a more detailed water table map.

The second student, Yaser Kishawi, that will be working on this project started in January and is also pursuing his Ph.D.. His expertise are in surface and groundwater modeling.

Research activities to date included:

- evaluating how the Palmer Drought Severity Index (PDSI) correlated to the area of the lakes over time
- acquiring historical and current (2018) Rapid Eye images of the study area
- setting up the surface water model for the Upper Middle Loup using SWAT

Future planned work includes calibrating the surface water model and then creating a groundwater model using MODFLOW. The models will then be coupled and multiple Red Cedar encroachment scenarios will be simulated. The students will predict Red Cedar encroachment based on current and alternative management for the next 10-100 years. A final report will be provided to NDNR, and the results will be presented at multiple national conferences.

Change in Knowledge/Action: **Yaser Kishawi** is continuing to work on his PhD at UNL as a Graduate Research Assistant. He also works as a freelance environmental consultant in the field of Environmental Modeling and Assessment.

- **Daran Rudnick**, Assistant Professor, UNL Biological Systems Engineering, for the project: *Sustaining Agriculture through Adaptive Management Resilient to a Declining Ogallala Aquifer and Changing Climate*. Ph.D. Student: **Tsz Him Lo**, for a Ph.D. in Biological Systems Engineering.

This award supplemented the graduate research assistantship stipend for Rudnick's Ph.D. student, Tsz Him Lo, who was recruited to join a multi-state and multidisciplinary project funded by the US Department of Agriculture (USDA) titled, "Sustaining Agriculture through Adaptive

Management Resilient to a Declining Ogallala Aquifer and Changing Climate." This project is a response to decreasing groundwater levels in substantial portions of the Ogallala Aquifer. Rudnick and Lo are part of teams focusing on: developing and identifying the best irrigation technologies, cropping systems management practices, and decision support tools to improve water use efficiency; and enable the adoption of tools and recommended strategies for improved water use through highly integrated and effective communication among the project them and technology transfer with stakeholders. Research activities have emphasized the deployment and evaluation of soil moisture sensors, thermal infrared sensors, and canopy reflectance sensors with varying spatiotemporal resolutions.

#### Presentations:

- Dorr, T., Singh, J., **Lo, T.**, & Rudnick, D. R. (2016). Performance analysis of factory, laboratory, and field calibrated soil water sensors for irrigation management. ASA, CSSA, & SSSA International Annual Meetings: Resilience Emerging from Scarcity and Abundance. November 6-9, 2016. Phoenix, Arizona.
- **Lo, T.**, Heeren, D. M., Luck, J. D., Haghighi, A., & Rudnick, D. R. (2016). Developing management zones for variable rate irrigation (VRI). Invited oral presentation at UNL Extension's Technologies for Irrigation Management field day, Elgin, NE.
- Oral presentation at Daugherty Water for Food Global Institute Research Forum, Lincoln, NE.
- **Lo, T.**, Rudnick, D. R., Heeren, D. M., Luck, J. D., & Shaver, T. M. (2016). Variable rate irrigation (VRI): An introduction. Invited oral presentation at NRCS Nebraska Irrigation Forum, Grand Island, NE.
- Oral presentation at Central Plains Irrigation Conference, Burlington, CO.
- Rudnick, D. R., Dorr, T., & **Lo, T.** (2017). Irrigation scheduling using soil water sensors. Ag Innovators Series - Improving Economic Efficiency through Precision Ag Technology. January 19, 2017. Yuma, Colorado.
- Rudnick, D. R., **Lo, T.** (2016). Variable rate irrigation: How does it work and what are the advantages for the farmer. *5<sup>th</sup> International Meeting on "Efficient use of Water for Irrigation"*. Hosted by National Institute of Agricultural Technology (INTA). October 26-27, 2016. Manfredi, Cordoba Province, Argentina.
- Shaver, T. M., Ferguson, R. B., Rudnick, D. R., & **Lo, T.** (2017). Integrating variable rate nitrogen and variable rate irrigation management: Opportunities and challenges. Oral presentation at Central Plains Irrigation Conference, Burlington, CO.
- Singh, J., **Lo, T.**, Rudnick, D. R., Dorr, T. J., Burr, C. A., Werle, R., Shaver, T. M., & Munoz-Arriola, F. (2017). Performance analysis of electromagnetic soil water sensors in a loam soil. Poster presentation at Water for Food Global Conference, Lincoln, NE.

#### Publications:

- Lo, Tsz Him; Rudnick, Daran; Krienke, Brian; Heeren, D. M.; Ge, Yufeng; and Shaver, Tim M., "Water effects on optical canopy sensing for late-season site-specific nitrogen management of maize." *Computers and Electronics in Agriculture* 162 (2019), pp 154–164.  
<https://digitalcommons.unl.edu/biosysengfacpub/617>.
- **Lo, T.**, D.R. Rudnick, Y. Ge, D.M. Heeren, S. Irmak, J.B. Barker, X. Qiao, T. M. Shaver (2018). Ground-Based Thermal Sensing of Field Crops and Its Relevance to Irrigation Management (Nebraska Extension Publication G2301)

- Rudnick, D.R., **T. Lo**, J. Singh, R. Werle, F. Muñoz-Arriola, T. Shaver, C.A. Burr, and T.J. Dorr (2018). Letter to the Editor: Reply to comments on “Performance assessment of factory and field calibrations for electromagnetic sensors in a loam soil”. *Agricultural Water Management* 203 (2018) 272–276.
- Singh, J., **T. Lo**, D.R. Rudnick, T.J. Dorr, C.A. Burr, R. Werle, T.M. Shaver, & F. Muñoz-Arriola. (2018). Performance assessment of factory and field calibrations for electromagnetic sensors in a loam soil. *Agricultural Water Management*, 196:87-98
- Lo, T., D. M. Heeren, L. Mateos, J. D. Luck, D. L. Martin, K. A. Miller, J. B. Barker, and T. M. Shaver. 2017. Field characterization of field capacity and root zone available water capacity for variable rate irrigation. *Applied Engineering in Agriculture* 33(4): 559-572.  
<https://doi.org/10.13031/aea.11963>.
- **Lo, T.**, Rudnick, D. R., & Shaver, T. M. (2017). Sensor-based site-specific management of irrigation and fertilizer.
- **Lo, T.**, Rudnick, D. R., Heeren, D. M., Luck, J. D., & Shaver, T. M. (2017). Fundamentals of variable rate irrigation.
- Singh, J., **Lo, T.**, Rudnick, D. R., Dorr, T. J., Burr, C. A., Werle, R., Shaver, T. M., & Munoz-Arriola, F. (2017). Performance analysis of electromagnetic soil water sensors in a loam soil. Manuscript under review.
- Lo, T., D. M. Heeren, D. L. Martin, L. Mateos, J. D. Luck, and D. E. Eisenhauer. 2016. Pumpage reduction by using variable rate irrigation to mine undepleted soil water. *Transactions of the ASABE* 59(5): 1285-1298, doi: 10.13031/trans.59.11773.  
<https://digitalcommons.unl.edu/biosysengfacpub/454/>.
- DISSERTATION: Lo, Tsz Him, "Water and Nitrogen Interactions in Maize Production" (2018). ETD collection for University of Nebraska - Lincoln.  
<https://digitalcommons.unl.edu/dissertations/AAI10982734>.

Changes in Knowledge/Action: Tsz Him Lo plans to graduate in December 2018. The overarching multi-state, multi-disciplinary project is expected to continue. In addition to presentations and publications, more deliverables, such as software tools and technical contributions, are expected.

This project has also generated synergy with three other projects:

1. a USDA-funded project on fertigation, seeking to reduce nitrogen inputs and groundwater contamination while maintaining or improving economic outcomes;
2. a USDA-funded project on integrating and evaluating unmanned aircraft systems and a remote sensing- driven evapotranspiration model, with which three DWFI-supported graduate students are associated; and
3. UNL Testing Ag Performance Solutions (UNL-TAPS) 2nd Annual Farm Management Competition ([www.taps.unl.edu](http://www.taps.unl.edu)), which engages corn producers simultaneously on the same field as a basis for innovative research and extension. Tsz Him Lo has assisted with all these projects and looks forward to increasing opportunities to collaborate in mutually beneficial ways.

## Round Four

### Daugherty Graduate Research Assistantships – MS and Ph.D. positions

In 2017 eleven awards were given to support graduate student research, ten of which are still active in FY19. Faculty Fellows secured additional funds on their own to support the students, matching DWFI funds one-to-one. Undergraduate student support was also awarded once again to the Platte River Timelapse Project.

- **P. Stephen Baenziger**, Professor, UNL Agronomy & Horticulture, for the project: *Genetic Architecture of Male Traits for Hybrid Wheat Seed Production*.

Ph.D. Student: **Nicholas Garst**, for a Ph.D. in Agronomy (Plant Breeding and Genetics Emphasis)



Hybridizing traditionally self-pollinated crops such as wheat offers both yield advantages of 3.5% to 15% and greater yield stability in low water and high heat environments when compared to commercial self-pollinated cultivars. Hybrid wheat was attempted in the past with low commercial success due to the high cost of seed to the producer. If hybrids are to be deployed on a large scale, seed production costs need to decrease. This can be accomplished by changing the floral architecture of the wheat spike to encourage outcrossing. In this study, Mr. Garst is working on the male characteristics to facilitate pollination in hybrid wheat production fields. His project is part of an ongoing effort to create a public platform for hybrid wheat.

Nicholas is currently a third year Ph.D. student who is working on wheat breeding and genetics in the Department of Agronomy and Horticulture. Nicholas formed his committee, has an approved dissertation project, and will also pursue a minor in Statistics. Nicholas is in the process of completing his qualifying exams and is expected to finish mid-May 2019. Roughly 44 credit hours of coursework has been completed with areas of emphasis in genomics, plant breeding, and statistics.

His research activities to date include:

- developed the field trial randomization and did the seed preparation for the hybrid yield trial which consists of ~800 plots per location at 6 locations in both Nebraska and Texas (planted fall 2017 & 2018);
- designed and prepared the Hard Winter Wheat Association Mapping Panel (HWWAMP)—a key part of his dissertation, chemical hybridizing agent (CHA) optimization trial, and the small scale hybrid seed production trial;
- sprayed for CHA trial occurred in May 2018. The purpose of this experiment is to determine the best CHA rate and adjuvant mixture to male sterilize wheat so that hybrids can be made through cross-pollination; and
- conducted growth chamber experiments to examine heat's effect on pollination.



Presentations: Nicholas has presented his masters and initial Ph.D. work at International Annual Meeting of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America (Minneapolis, MN, November 2015), International Wheat Yield Partnership Grant Meeting at the Plant and Animal Genome Conference (January, 2017), International Wheat Yield Partnership Hybrid Wheat Update Meeting (April, 2018), and Daugherty Water for Food Conference (April, 2018), International Wheat Yield Partnership Hybrid Wheat Update Meeting (April, 2019), and Daugherty Water for Food Research Forum (April, 2019).

Publications:

Changes in Knowledge/Action: **Nicholas Garst** is continuing his PhD research at UNL, with an expected graduate date of 2020.

HWWAMP represents the diversity of hard winter wheat previously and currently grown in the Great Plains (includes lines from Texas to North Dakota, from Kansas to Montana, and from the public and private sector). The advantage of the HWWAMP is that genotyping data are freely available. Hence we can use our phenotypic data, access the publicly available genotypic data, and genetically analyze our traits.

Hybrid seed production yields have increased by nearly 100% since the first production trial was planted in 2015. Increasing seed production is critically important as it directly relates to the cost of hybrid seed that growers have to pay. The cost of seed also determines the level of heterosis that growers need to grow economically sustainable hybrid wheat. The first seed production trial averaged ~300 grams per female plot while the 2017 production trial averaged over 600 grams. The highest yielding family of crosses in the first year averaged 768 grams while the trial in 2017 had a hybrid family averaging nearly 1000 grams. Cross pollination success, comparing female production yield to the average breeding trial plot yields, has increased from 15% to 45%.

- **Yufeng Ge**, Assistant Professor, UNL Biological Systems Engineering, for the project: *Integrated crop and soil water sensor network to assist UAS and soil water simulation modeling in variable rate irrigation*.  
Ph.D. Student: **Jasreman Singh**, for a Ph.D. in Biological Systems Engineering (Soil and Water Resources Engineering Emphasis).

Five sensor nodes were installed in the VRI field at Mead in the 2017 season. The sensor node included the NDVI sensor, the IRT canopy temperature sensor, and 3 volumetric soil moisture sensors at three depths. In 2018, we worked to add more sensing capabilities to the sensor node with additional micro-environmental sensors (for solar radiation, wind speed, air temperature and relative humidity). We also worked with the collaborator at Colorado State University on wireless data communication between UAV and sensor nodes (the data-mule concept). Field work in the 2018 season included the installation of 12 sensor nodes. For the year 2019, the research focus will be deployment of a new sensor (Raspberry-Pi based RGB imaging system) to the integrated soil and plant sensor network to aid in variable rate irrigation decision making. To accomplish this objective, the imaging sensor was developed and tested in the laboratory. This sensor will be deployed to each



of the 12 soil and plant sensor network sites in the field. It will aid in measuring crop canopy cover in addition to the soil and vegetation parameters being determined. The main intent of these sensor nodes is to calibrate and validate the aerial and thermal imagery from unmanned aerial vehicle (UAV) systems, and the soil moisture dataset would be used to correct for soil moisture modelling from SETMI model.

Presentations:

- Bhatti, S., Kumari, A., Sarangi, A., Heeren, D. M., Kaur, R., Neale, C.M.U., Singh, M. July 7-10, 2019. Integrated Soil Moisture and Canopy Temperature Sensing System for Irrigation Scheduling. Presented at ASABE AIM 2019. Boston, MA, USA.
- Singh, J., Heeren, D.M., Rudnick, D.R., Barker, J.B., Woldt, W.E., Ge, Y., Luck, J.D., Bai, G., Meyer, G., Neale, C.M.U. July 7-10, 2019. Soil Structure and Texture Effects on the Precision of Soil Water Content Measurements by a Capacitance-based Electromagnetic Sensor. Presented at ASABE AIM 2019. Boston, MA, USA.
- (POSTER) Singh, J., Ge, Y., Bai, G., Barker, J.B., Heeren, D.M., and Neale, C.M.U. April 29-30, 2019. In-field soil and plant sensor network to improve variable rate irrigation decision-making. Presented at Water for Food Global Conference. Lincoln, NE, USA.
- (POSTER) Singh, J., Ge, Y., Bai, G., Barker, J.B., Heeren, D.M., Neale, C.M.U. October 24-26, 2018. In-field soil and plant sensor network to improve variable rate irrigation decision-making. Presented at Nebraska Water Center Great Plains Regional Water Symposium. Lincoln, NE, USA.
- Singh, J., Ge, Y., Bai, G. July 29-August 1, 2018. In-Field Soil and Plant Sensor Network to Improve Variable Rate Irrigation Efficiency. American Society of Agricultural and Biological Engineers (ASABE) Presented at ASABE AIM 2018, Detroit, MI, USA.

Publications:

- Singh, J., D. M. Heeren, D. R. Rudnick, W. E. Woldt, Y. Ge, and J. D. Luck. 2019. Soil structure and texture effects on the precision of soil water content measurements by a capacitance-based electromagnetic sensor. Transactions of the ASABE (in review).

Changes in Knowledge/Action: TBD

- [James D. Goedert](#), Emeritus Professor, Durham School of Architectural Engineering and Construction, for the project: *Growing Haiti*  
The first student recruited for the project transferred; a subsequent student has yet to be recruited.

- **Jesse Korus**, Assistant Professor, UNL School of Natural Resources, for the project: *Improving Groundwater Characterization and Management through Integration of Airborne Electromagnetics (AEM) and Borehole Data*.

Masters Student: **Jaqueline Polashek**, for a M.S. in Natural Resource Sciences



**Presentations:** Live demonstration of the GeoScene3D project to ~120 water resources managers, specialists, and technicians at the annual NRD Water Programs conference; Water for Food Research Forum, April 26, 2018;

**Publications:**

**Changes in Knowledge/Action:** **Ms. Polashek** has finalized her MS research proposal and presented it to her committee. She will graduate in 2019, and is interested in attaining her professional geologist license and working in the hydrogeology field.

The project has been successful. We have had very productive meetings with the Lower Platte North NRD and the NE Department of Natural Resources, identifying mutual benefits of the project for all partners, resulting in a tentative agreement by our sponsors to co-fund additional monitoring sites in the study area. The agreement will result in an additional \$32,000 from project sponsors, plus \$12,000 from a grant to Dr. Korus, totaling \$44,000 for monitoring instrumentation. The instruments will be used for research as well as groundwater management.

- **Taro Mieno**, Assistant Professor, UNL Agricultural Economics, for the project: *Farmer adaptation to low well yields in high-productivity irrigated agriculture*.

Masters Student: **Paloch Suchato**, for a M.S. in Agricultural Economics



Our preliminary results suggest that insurance does not affect the amount of irrigation water that a producer chooses to apply. However, this is a very preliminary result, and we are skeptical of this outcome. There are some biases associated with these estimates, because they only include the risks that are incorporated in Aquacrop-OS (i.e., most of the weather-related production risks), but not all of them, such as hail damage. Because of this deficiency, our preliminary results suggest that farmers are better off without crop insurance at all, which seems to be at odds with USDA RMA reports about how widespread crop insurance coverage is in the region. Thus, we turned to data maintained by the USDA Risk Management Agency, and we found that there are indeed significant numbers of claims for hail damage. One of our next steps is to incorporate this kind of production risk into the analysis so that the value of crop insurance reflects all of the risks facing agricultural producers.

**Presentations:** Water for Food Research Forum, April 26, 2018

Publications:

- THESIS: Suchato, Paloch. The Potential for Moral Hazard Behavior in Irrigation Decisions Under Crop Insurance. (2019). ETD collection for University of Nebraska - Lincoln. <https://digitalcommons.unl.edu/embargotheses/159/>.

Changes in Knowledge/Action: **Paloch Suchato** is anticipating to graduate in 2019. He continues to work as a Research Assistant at UNL (Aug 2017 – present).

- **Xu Li**, Associate Professor, UNL Civil Engineering, for the project: *Determination of Setback Distance Requirements for Reducing Contaminants in Agricultural Runoff Following the Land Application of Swine Manure Slurry*.  
Masters Student: **Maria Cecilia Hall**, for an M.S. in Environmental Engineering



Presentations:

- Water for Food Research Forum, April 26, 2018

Publications:

- THESIS: Hall, Maria. INFLUENCE OF SWINE MANURE STORAGE AND LAND APPLICATION PRACTICES ON MITIGATING THE SPREAD OF ANTIBIOTIC RESISTANCE IN THE ENVIRONMENT. (2018) <https://digitalcommons.unl.edu/embargotheses/143/>.

Changes in Knowledge/Action: **Cecilia Hall** graduated in December 2018 and has gone on to work as an Applications Analyst in the Environmental Science & Support department at LI-COR Biosciences.

A large experimental data set has been generated for the two National Pork Board projects. The data generated will be used to write at least three manuscripts. Through these publications, the findings from the project could reach both the research community and the stakeholders (i.e., livestock and crop producers). When producers use the findings from the study to treat and apply livestock manure, it is expected that manure-borne antibiotics and ARGs, two classes of contaminants of emerging concerns, will have less negative impacts on surface water under agricultural influences.

- **Yusong Li**, Associate Professor, UNL Civil Engineering, for the project: *Influence of Climate and Agricultural Clustering on Groundwater Contamination by Trace Organics*.

Ph.D. Student: **Chuyang Liu**, for a Ph.D. in Civil Engineering



Over the grant period, we have (1) developed an agricultural nonpoint source pollution potential index (APPI) to evaluate the spatial distribution of nonpoint source pollution (NPS) risks in the United States; (2) evaluated the uncertainties related to predict atrazine spatial distribution under historic and future climate scenarios. In the next year, we will further extend the efforts. We will validate the APPI using available water quality data, particularly in Nebraska. We also plan to incorporate the pesticide use into the APPI. We will predict atrazine spatial distribution with uncertainty under multiple climate scenarios.

#### Presentations:

- Liu, C.Y.; Li, Y.; Bartlet-Hunt, S. Predict the Transport of Atrazine under Future Climate Scenarios beneath Nebraska's Management Systems Evaluation Area. World Environmental and Water Resources Congress., May 19-23, 2019, Pittsburg, PA.
- Liu, C.Y.; Li, Y.; Bartlet-Hunt, S. Predict the Transport of Atrazine under Future Climate Scenarios beneath Nebraska's Management Systems Evaluation Area. 2019 Water for Food Global Conference, Lincoln, NE, April 29-30, 2019.
- Liu, C.Y.; Li, Y.; Bartlet-Hunt, S.; Yang, F. Predict the Spatial Distribution of Agricultural Nonpoint Pollution Potential in the Contiguous United States. Nebraska Water Center Symposium, March 2019.
- "9th International Congress on Environmental Modelling and Software-Modelling for Sustainable Food-Energy-Water Systems"(iEMSs 2018), June 24-28, in Fort Collins, Colorado.
- Bartelt-Hunt, S.L. and Li, Y. (2018). Influence of climate on the fate of trace organics in groundwater. Water, Sustainability and Climate Investigator's Meeting, Washington D.C., Jan 29-31, 2018.
- Akbariyeh, S.; Gomez, C. ; Bartelt-Hunt, S.; Li, Y Predicting Nitrate Transport under Future Climate Scenarios beneath the Nebraska Management Systems Evaluation Area (MSEA) site , AGU Fall Conference, New Orleans, December 11-15, 2017.
- Akbariyeh, S.; Gomez, C.; Barrios, R.; Li, X.; Bartelt-Hunt, S.; Li, Y., Predicting nitrate transport under future climate conditions for agricultural lands. MGWA Fall Conference, St. Paul, MN, November 15, 2017.
- Akbariyeh, S.; Gomez, C.; Barrios, R.; Li, X.; Bartelt-Hunt, S.; Li, Y., Impacts of climate change on nitrate transport beneath a center-pivot irrigated corn field. AEESP Conference, June 22-27, 2017, Ann Arbor, MI.

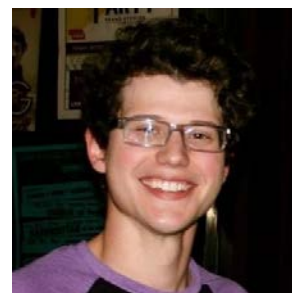
#### Publications:

- Akbariyeh, S. ; Gomez Pena, C.A. ; Wang, T.; Mohebbi, A.; Bartlet-Hunt, S.; Zhang, J.; and Li, Y., Predicting the Leaching and Accumulation of Nitrate-N beneath a Center-Pivot Irrigated Corn Field under a Future Climate Scenario. 2019. *Science of the Total Environment* (In review after first revision)

- Akbariyeh, S.; Bartlett-Hunt, S.; Snow, D.; Li, X.; Tang, Z., and Li, Y., Three-Dimensional Modeling of Nitrate-N Transport in Vadose Zone: Roles of Soil Heterogeneity and Groundwater Flux. *Journal of Contaminate Hydrology*. Vol 211, April 2018, Page 15-25. <https://doi.org/10.1016/j.jconhyd.2018.02.005>.

Changes in Knowledge/Action: **Chuyang Liu** is continuing his PhD research at UNL, and is working as a Research Assistant to develop cost-effective devices to detect or remediate chemical mixtures in environmental media.

**Adam Liska**, Associate Professor, UNL Biological Systems Engineering and Agronomy & Horticulture, for the project: *Livestock Thermodynamics & Agricultural Energy Productivity Gaps in Sub-Saharan Africa*.  
Masters Student: **Calvin Harman**, for a M.S. in Natural Resource Sciences (Human Dimensions)



This project has been in progress since 2015, and theoretical issues have been explored since 2005. The broad goal of this project is to develop a more explicit theoretical understanding of agricultural productivity gaps (total energy productivity and thermodynamic energy efficiency) from crop production to final human consumption, which can result in novel management options to increase food security in Sub-Saharan Africa (SSA) by closing productivity gaps (total energy [i.e. calories] and protein productivity from crop production to human consumption). Calvin worked to enhance the methodology for the “animal ratio model” after correspondence with many experts. Results are based on metabolic energy demand during animal development. Results suggest that maize-equivalent conversion efficiency (i.e. the theoretical maximum energy transfer from maize, as the primary animal feed component, to humans via animal food products) is no more than ~10%.

#### Presentations:

- Presentation—CT Harman, ‘Thermodynamic Limitations to Agricultural Productivity and Food Security: Livestock in Sub-Saharan Africa’. Water for Food Research Forum, April 26, 2018.

#### Publications:

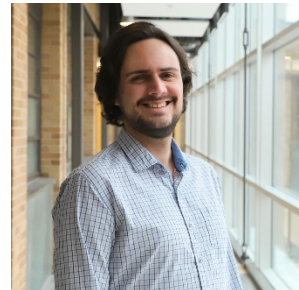
- Harman, Calvin, "A Call for Congressional Climate Action" (2014). Op-Eds from ENSC230 Energy and the Environment: Economics and Policies. 47. <http://digitalcommons.unl.edu/ageconugensc/47>.
- THESIS: Harman, C. (2017). Thermodynamic Limitations to Agricultural Productivity and Food Security: Livestock in Sub-Saharan Africa (master's thesis). University of Nebraska-Lincoln, Lincoln, NE, US. <https://digitalcommons.unl.edu/embargotheses/118/>.



Changes in Knowledge/Action: Calvin Harman is continuing his PhD research and works as a Graduate Research Assistant at UNL.

The project resulted in development of a more complete theoretical understanding of agricultural productivity gaps and management options to enable increased food security with reduced environmental impacts in SSA. For example, results indicate 5 Mg (5 metric tons) of maize grain could provide the yearly energy (calories) requirements of approximately 22 humans via direct consumption (bypassing livestock) or that of only 3 humans via chicken eggs. Calvin also assisted with lecturing and grading for Professor Liska's "Energy Science 110: Energy in Perspective" course.

- **James C. Schnable**, Associate Professor, UNL Agronomy & Horticulture, for the project: *Optimizing the water use efficiency of C4 grain crops using comparative phenomics and crop models to guide breeding targets*.  
Ph.D. Student: **Daniel Santana de Carvalho**, for a Ph.D. in Agronomy & Horticulture



This project had two main objectives:

1. Determine the role of variation in plant architecture and flowering time on the disparate water use efficiencies of maize, sorghum, as well as pearl, foxtail, and proso millet.
2. Determine the efficiency of the C4 photosynthetic cycle across ~45 grass species representing ~10 independent evolutionary origins of C4 photosynthesis.

Using the Greenhouse Innovation Center's automated phenotyping greenhouse, Schnable and de Carvalho monitored three accessions each of five related grain crop species which all employ C4 photosynthesis (maize, sorghum, pearl millet, foxtail millet, and proso millet) and all are grown extensively in one or more of DWF's geographic focus areas. The automated phenotyping greenhouse tracks change in water content on a daily basis to enable controlled water, making it possible to track total water use of each individual plant throughout the growing season.

#### Presentations:

This project has resulted in multiple outputs to date:

- A video discussing the relevance of studying water use efficiency in C4 grasses as a way to relief the strain in water resources (<https://www.youtube.com/watch?v=uF02kuE4Qn0&feature=youtu.be>).
- An oral presentation about water use efficiency in C4 grasses at the Water for Food Research Forum (April '18).
- A presentation at The 3rd International Symposium on Broomcorn Millet in August 2018 in Fort Collins, Colorado (<https://extension.unl.edu/statewide/panhandle/international-millet-symposium-2018/>) about how the images collected can help us improve proso millet breeding, helping us predict how the plant grows, quantify differences in water use efficiency between different cultivars and nondestructively monitor the uptake of nutrients (such as nitrogen and phosphorus) in vivo throughout the lifecycle of the plants.
- Posters presented at two conferences: the 2018 International Proso Millet Symposium and the 2019 Phenome Conference.

### Publications:

Two scientific journals written as part of the dissertation research:

- Isoseq transcriptome assembly of new C3 panicoid grasses provides insights about evolution of Poaceae (Carvalho DS and Schnable JC, in prep)
- Reconstructed protein sequence evolution suggests C4 photosynthesis evolved via a C2 ancestor in the Paniceae
- DISSERTATION: Carvalho, Daniel. An Integrated Genomics And Phenomics Approach To Study The Evolution Of C4 Photosynthesis. (2019) University of Nebraska-Lincoln, Lincoln, NE, US. <https://digitalcommons.unl.edu/agronhortdiss/170/>.

Changes in Knowledge/Action: Daniel Santana de Carvalho received the distinguished Henry M. Beachell Fellowship. This fellowship recognizes academic excellence and research potential in the agronomic and horticultural sciences.

This project generated an image dataset of 8 grass species, including both worldwide consumed crops and orphan crops such as: Japanese millet, finger millet, teff, proso millet, pearl millet and foxtail millet. The images successfully captured the entire life cycle of all grasses. This image dataset provided us with differences in plant growth throughout their life cycle. For instance, before 50 days the difference between both pearl millet genotypes seem to be about 0.5m. However, after 65 days old the height difference between them is about 1m. Such information can help more accurately create crop growth models for proso, pearl, foxtail and Japanese millet and teff. The data obtained for both maize and sorghum can be used to test how well previous growth model of these plants predict what was collected in this study, helping validate such models.

- **Karina Schoengold**, Associate Professor, UNL Agricultural Economics, for the project: *The Effects of Institutions and Hydrological Conditions on Optimal Management of a Shared Aquifer: a case study of the High Plains*. Masters Student: **Qianyu Zhang**, for an M.S. in Agricultural Economics



The research project focuses on examining the effects of groundwater policies and economic factors on the timing of well drilling decision in Nebraska. The primary focus is to analyze how groundwater policies, i.e. Well Drilling Moratorium, affect farmers' irrigation decisions based on the observations from 1990 to 2017 in nine NRDs in Nebraska.

Ms. Zhang has become proficient in R programming and the data analysis for the project. She has shown strong motivation and a commitment to doing high-quality work, and is scheduled to defend her MS thesis in summer 2019.

Qianyu's research activities to date include:

1. Collected spatial datasets on wells drilled in Nebraska from the NDNR website. Filtered out wells that are inactive or not for irrigation use. In total, there are 69,645 irrigation wells in the state overlaying the Nebraska portion of the High Plains aquifer included in our study region (nine NRDs).

2. Collected spatial datasets on agronomic factors (soil and climate/weather characteristics) and economic factors (commodity prices) likely to affect irrigation decision making. Since farmers' irrigation decisions do not solely depend on one year's observations, we use a five-year moving average for all time-varying variables. Our study period to analyze policy variables is between 1990 and 2017.
3. Conducted statistical analysis called survival analysis, which examines the probability that farmers remain in dryland production until a specific year to switch to irrigated production.

Presentations:

- Water for Food Research Forum, April 2018 and 2019

Publications:

- THESIS: Zhang, Q. (2019). "The Effects of Economic Factors and Groundwater Policies on the Timing of Well Drilling". University of Nebraska-Lincoln.  
<https://digitalcommons.unl.edu/agecondiss/55/>.

Changes in Knowledge/Action: **Qianyu Zhang** anticipates a graduate date of 2019, and is currently working as a Research Assistant at UNL. She gained numerous professional skills during her work, including: Developed fundamental knowledge to conduct environmental policy analyses and make applicable conclusions in terms of groundwater management in Nebraska; Acquired and sufficiently used R for cleaning, processing and organizing multiple complex datasets for empirical analyses; Worked intensively with geographic information systems (GIS) to manage large spatial datasets and gain insights through data visualization.

Results of the project demonstrated that before a well-drilling moratorium, the probability of drilling a new well increases by 2.6%. On the contrary, after the well drilling moratorium, farmers decrease the probability of drilling a well by 62%. The result for peer effect is negative and statistically significant, which is inconsistent with our expectation and the results from previous study by Sampson and Perry (2018). Our hypothesis on peer effect was positive, because if a moratorium is implemented in an adjacent NRD, the probability of farmers drilling a new well increases due to the expectation of such policy to expand to their own NRD in the future. Energy costs are negatively related to farmers' irrigation decisions, and as revenue differentials increase, it tends to increase the probability of drilling a new well, especially for corn revenue differentials.

- **Karrie Weber**, Associate Professor, UNL School of Biological Sciences, for the project:  
*Mobilization of Naturally Occurring Uranium into Groundwater*  
 Ph.D. Student: **Jeffrey Westrop**, for a Ph.D. in Geology

Concentrations of soluble uranium (U) above the US Environmental Protection Agency's Maximum Contaminant Level (EPA MCL) of 30ug/L have been reported in many US aquifers. Elevated groundwater U concentrations are a significant public health risk and treatment options can exceed one million dollars, making them an economic burden. Therefore, understanding the processes that mobilize U in these systems is necessary to develop management strategies and prevent further drinking water contamination. Overall, these

experiments demonstrated the mobilization of naturally occurring uranium following nitrate inputs. Future work includes identifying the amount of nitrate required to initiate U mobilization from natural sediments.

Presentations:

- Weber, K. A. It's all about U: Anthropogenic Mobilization of Uranium in Alluvial Aquifers. Colorado State University, Department of Crop and Soil Science. October 4, 2018.
- Weber, K. A. Naturally Occurring Uranium in Groundwater and Links to Nitrate. SIWI World Water Week, Stockholm, Sweden. August 28, 2018.
- Weber, K. A. Microbiological controls governing uranium redox behavior in microaerophilic reduced sediments. Stanford Light Accelerator Laboratory and Stanford University Department of Earth System Science. July 26, 2018.
- Weber, K. A. Mobilization of Uranium in Alluvial Aquifers: What is the role of oxygen and nitrate? Geology, Geophysics, and Geochemistry Science Center. Denver, CO. May 23, 2018.
- Weber, K. A., J. Westrop, J. Nolan, S. Bone, J. Bargar, K. Campbell-Hay, and D. Snow. Microbially-mediated metal/radionuclide oxidation coupled to nitrate reduction in an alluvial aquifer. American Chemical Society Spring Meeting. New Orleans, LA.
- Weber, K. A. Co-contaminants and Redox Chemistry: Nitrate Mediated Mobilization of Naturally Occurring Uranium in Groundwater. Water Quality Symposium, Water for Food Institute and Nebraska Water Center. October 26, 2017.
- Weber, K.A. Nitrogen mediated metal redox cycling. American Chemical Society Spring Meeting, San Francisco, CA April 2-6, 2017.
- Weber, K. A. Life beneath our Feet: Influence on Water Quality—Nitrate and Uranium. Indo-US Workshop Addressing the Nexus of Food, Energy and Water. Bangaluru, India. April 20, 2017
- Weber, K. A. Mobilization of Uranium in Groundwater: What is the role of nitrate? Nebraska Water Center. April 13, 2016
- Weber, K.A. Uranium and Nitrate in Groundwater. Nebraska Natural Resource District Conference, Kearney, NE, March 1, 2016.
- Weber, K.A. Uranium mobilization in groundwater and the role of nitrate. Little Blue Natural Resource District, Edgar, NE, December 1, 2015.
- Weber, K. A. Life Beneath Our Feet: Influence on Water Quality, Department of Geography and Geology, University of Nebraska, Omaha, November 5, 2015.
- Weber, K. A. Water Quality Impacts of Highly Intensive Agriculture. National Institute of Water Resources Regional Symposium. Water Resources of the Great Plains Region Status and Future. Lincoln, NE. October 24-27, 2018.

#### Publications:

- Pan, D., R. Watson, D. Wang, Z. H. Tan, D. Snow, K. A. Weber. 2014. Correlation between viral production and carbon mineralization under nitrate reducing conditions in aquifer sediment. *The ISME Journal*. 8: 1691-703. doi:10.1038/ismej.2014.38
- Nolan, J. P., K. A. Weber. Natural uranium contamination in major US aquifers linked to nitrate. 2015. *Environmental Science and Technology Letters*. 2: 215-220. doi:10.1021/acs.estlett.5b00174 \*Press coverage \*Highlighted as Editor's Choice in Science
- Pan, D., J. Nolan, K. H. Williams, M. J. Robbins, K. A. Weber\*. 2017. Abundance and Distribution of Microbial Cells and Viruses in an Alluvial Aquifer. *Frontiers in Microbiology*. 8: 1199. doi: 10.3389/fmicb.2017.01199
- Pan, D. K. H. Williams, M. J. Robbins, K. A. Weber. 2018. Uranium Retention in a Bioreduced Region of an Alluvial Aquifer Induced by the Influx of Dissolved Oxygen. *Environmental Science and Technology*. 52 (15), 8133-814.
- Nolan, J., S. Bone, K. Campbell, D. Pan, O. Healy, C. Elofson, R. M. Joeckel, M. Stange, T. Wilson, P. Hanson, J. Bargar, and K. A. Weber. Naturally Occurring Uranium in an Oxic Alluvial Aquifer. (in preparation for *Chemical Geology*)
- Malakar, A., D. D. Snow, K. A. Weber. One-step facile synthesis of nanosized uranium dioxide (UO<sub>2</sub>) (in preparation)
- Westrop, J.P., D.D. Snow, K.A. Weber. Mobilization of naturally occurring uranium under intensely farmed cropland (in preparation)
- Westrop, J.P., J. Nolan, O. Healy, K. M. Campbell, D.D. Snow, J. Barger, S. Bone, K.A. Weber. Nitrate driven uranium mobilization from natural sediments (in preparation)

Changes in Knowledge/Action: TBD

#### **Daugherty Undergraduate Scholars**

- **Michael Farrell and Mike Forsberg**, Assistant Professors of Practice, UNL Agricultural Leadership, Education and Communication, for the project *Platte Basin Timelapse*.  
Students: **Merika Andrade, Joe Arneson, Grace Bullington, Michaela Daugherty, Mikaela Deptula, Ethan Freese, Carlee Koehler, Mariah Lundgren, Alex (Alexandria) Lundvall, Zoe Mays, Amy Morris, Grant Reiner, Gabriella Parsons, Andrew Wentz**

Presentations: Key to this Platte Basin Timelapse Project's success so far has been recruiting and training a pool of emerging talented young people through paid internships.

- *Global Water for Food Conference*, Seattle, Washington, October 19-22, 2014 (poster)
- DWF Student Support Research Forums, 2015-2018.
- Sunday with a Scientist, Lincoln, NE, June 12, 2016.
- Timelapse videos available at: <http://plattebasintimelapse.com/>
- Developed a large screen display for public engagement at the Crane Trust Visitors' Center.

Changes in Knowledge/Action: Mariah Lundgren graduated December 2014 and is now working part-time for the project supervising interns. Joe Arneson graduated May 2015. The following graduated May 2018: Merika Andrade, Grace Bullington, Ethan Freese, Alex (Alexandria) Lundvall, Grant Reiner.

The project has established funding relationships with the Nebraska Corn and Soybean Boards and several others.



## Round Five

### Daugherty Graduate Research Assistantships – MS and Ph.D. positions

In 2018, nine awards were given to support graduate student research. Again, Faculty Fellows secured additional funds on their own to support the students, matching DWF funds one-to-one. Note: one award (to Bruce Dvorak for Shaobin Li) is for summer support only. Derek Heeren and Bing Wang opted to delay the start of their awards until January 2019.

- **Cody Creech**, Assistant Professor, UNL Agronomy & Horticulture, for the project: *Wheat Residue Management to Enhance Soil Water Conservation*. Masters Student: **Luana Machado Simão**, for a M.S. in Agronomy



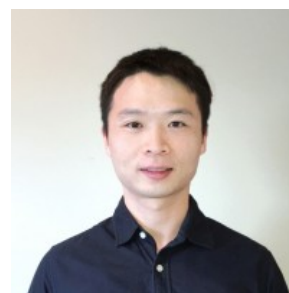
Wheat production has persisted in the driest areas because of the efficient water use of the crop and because of the substantial amount of residue produced. This residue, if managed properly, can protect the soil from erosion and conserve valuable soil moisture. The objective of this research is to identify wheat characteristics that enable the wheat residue to persist for a longer period of time and provide greater benefit to the following year's crops.

This experiment was initiated in 2016 at the High Plains Agricultural Laboratory near Sidney, NE. Five varieties of winter wheat were planted representative of five characteristics: 1) Tall; 2) Short; 3) Strong Stem; 4) Weak Stem; and 5) Solid Stem. These plots were rotated with corn, including two crops of wheat and corn each. As soon as the corn emerged, neutron probes were installed to monitor changes in soil moisture. Corn yield data was collected. The wheat residue measurements (collected every 2 months), soil moisture, and corn yield data are being analyzed for correlations. If differences exist, an economic analysis will be performed to identify the most profitable wheat variety considering not only the wheat yield but also the corn yield.

Luana Simão has started this project. She arrived in August 2018. She completed her classwork in the Spring 2019 semester, and subsequently moved to Sidney, NE where she is focusing on completing her research and writing. Previously, Luana served in Creech's research lab as an undergraduate Brazilian intern during the summer of 2017.

**Presentations:** Luana presented at the Robert B. Daugherty Water for Food Global Institute's annual research forum in 2019 providing an update on the findings up to this point. Research was shared at a field day one June 20 and August 13, 2019 at the High Plains Ag Lab near Sidney, NE with area producers and industry partners.

- **Bruce Dvorak**, Professor, UNL Civil Engineering & Biological Systems Engineering, for the project: *Framework for assessing microbial reduction and environmental impacts of food systems: Implications on improving water conservation and wastewater quality in U.S. beef processing industry*.



Ph.D. Student: **Shaobin Li**, for a Ph.D. in Civil Engineering with specialization in Environmental Engineering (expected graduation: August 2019)

This project will design and evaluate a wide range of antimicrobial intervention combinations in the beef processing industry, and suggest combinations that will improve water conservation and wastewater quality without compromising the beef safety. This project will also provide guidance for the development of new antimicrobial interventions concerning which types of processes may offer the greatest potential for reducing water use and overall environmental footprint while minimizing the impact on food safety. Research activities to date included:

- Collecting data on various antimicrobials interventions using on-site data collection, public literature, suppliers data, and estimates based on scientific theory
- Evaluating 40 antimicrobial systems on the basis of microbial load reduction, environmental, and economic impacts, by meta-analysis, life cycle assessment, and operational cost analysis orderly

Presentations:

- International Society for Industrial Ecology conference, July 2019

Publications:

- One publication in a peer-reviewed journal (under-reviewed in Science of the Total Environment). Once the manuscript has been accepted in a peer-review journal, we will work with Dr. J. Subbiah to contact key players in the beef packing industry to share the results through in-person and/or zoom meetings.

Changes in Knowledge/Action: The results show that the antimicrobial systems applying steam pasteurization during the main intervention offer high microbial load reduction. Environmental and economic analyses reveal that human and ecosystem toxicity, eutrophication and global warming are the main contributors to the overall environmental impacts while antimicrobial chemicals, wastewater treatment, and natural gas are the three major drivers of operational cost. Devalued (discolored) meat due to contact with heat from steam pasteurization or hot water wash has a considerable increase in environmental and economic impacts. Certain antimicrobial systems (e.g., water wash followed by steam pasteurization) were found to be more promising with satisfactory effectiveness, better environmental and cost performance under uncertainty (1,000 Monte Carlo simulations). Results will be published and presented at conferences to provide suggestions for process engineers and microbiologists when they develop new antimicrobial systems in the meat packing industry, environmental engineers as they consider needed water and wastewater treatment capacity, and the management team who is focused on reducing the cost of operation.

- **Roger Elmore**, Professor, UNL Agronomy & Horticulture, for the project: *Isolating Primary Factors for Corn Ear Formation Issues*.  
Ph.D. Student: **Osler Antonio Ortiz-Amador**, for a Ph.D. in Agronomy



In 2016, reports were received from a number of producers and consultants that were experiencing ear development issues in corn fields, some of which had not been previously described in the literature. Affected (with ear issues) and unaffected (without ear issues) plants were sampled from 16 farmer fields of Central and Eastern Nebraska in 2016 and 2017, which showed that various ear issues could occur within the same field.

In 2018, seven experimental sites (three UNL Farms and four industry trials) were conducted to study causal agents of ear formation issues in corn. Factors studied were: eight hybrids, four susceptible (with ear issue reports in past years) and four tolerant (without ear issue reports in past years); four planting dates (from late April through late May); five seeding rates (from 18000 seeds per acre to 50000 seeds per acre); and seven hourly delayed planting times (ranging between zero and 270 hours). Plants from the two center rows in all fields were individually assessed for ear formation issues prior to harvest (about 55000 plants in total). From the assessed plants, 3514 of them displayed issues (about 7% of total). Issues observed varied: short husks (more than 25% of ear length exposed), multi-ears (more than one ear on the same node), tip back (more than 25% of kernels on ear tip missing), and abnormal ears. Data collection on plant samples from 2018 fields is underway. The greenhouse and growth chamber study will be initiated in 2019 to study specific stress agents (temperatures and ethylene concentrations) and their impact at critical timings of ear and kernel development.

#### Presentations:

##### *Seminar Presentations*

- Corn Growth & Development: Ear issues, Water for Food Research Forum, 2019.
- What we have learned from studying ears issues, Hoegemeyer Seeds Seminar, 2019.
- What we have learned from studying ears issues, UNL Nebraska Crop Mgmt. Conference, 2019.
- Ear Formation Issues in Corn, Corteva Agriscience Seminars (2), 2018.
- Ear Formation Issues in Corn, UNL South Central Agricultural Lab Field Day, 2018.

##### *Poster Presentations*

- Ear Formation Issues in Corn: a Field Survey, Water for Food Global Conference, 2019.
- Ear Formation Issues in Corn, UNL Plant Sciences Symposium, 2019.
- Ear Formation Issues in Corn: a Field Survey, ASA-CSSA-SSSA International Meetings, 2018.
- Delayed Emergence Impact on Ear Issues, ASA-CSSA-SSSA International Meetings, 2018.

#### Publications:

##### *Extension Publications*

- 2019 – Nebraska Farmer: [Does planting date affect corn growth, ear issues?](#)
- 2019 – UNL CropWatch: [Planting Date Impact on Corn Growth and Ear Issues](#)
- 2019 – UNL CropWatch: [Corn Development from Studying Ear Issues](#)
- 2019 – UNL Crop Management Conference Proceedings: [Corn Growth and development](#)
- 2019 – North Central Integrated Pest Management Center: [Corn Growth and Development](#)

- 2018 – UNL South Central Agricultural Lab Field Day Proceedings (pp. 8-9): [Ear Issues in Corn](#)

Changes in Knowledge/Action: Osler received multiple notable recognitions during the 2018-2019 school year, including: Water for Food Global Conference, 1<sup>st</sup> place online graduate student poster competition, 2019; Excellence in Agriculture Scholarship, National Corn Growers Association & BASF Corp., 2019; Third Place Ph.D. Oral Competition, American Society of Agronomy International Conference, 2018; The Love of Learning Award, Honor Society of Phi Kappa Phi, 2018; Graduate Scholar Award, International Plant Nutrition Institute (IPNI), 2018; Yield-Limiting Factors Grad Student Award, American Society of Agronomy, 2018.

Identifying and isolating factors associated and responsible for ear development issues in corn is important for understanding the likelihood of future events and to provide critical information necessary to potentially manage and mitigate these issues in the future. By identifying the causal agent (s), corn breeding programs will be able to use the information in their screening processes, and/or farmers will be able to adjust management practices to mitigate the issues and ultimately reduce productivity and at same time quality losses in corn. By understanding and mitigating these issues, agricultural productivity and quality losses in corn will be reduced and resources will be optimized.

- [Derek Heeren](#), Associate Professor, UNL Biological Systems Engineering, for the project: *Sensor-Based Irrigation Management for Maize and Soybean in the Great Plains*

Ph.D. Student: **Sandeep Bhatti**, for an Ph.D. in Biological Systems Engineering

The objectives of this project are to: 1) develop a best management practice for managing conventional irrigation and speed-control irrigation based on Watermark soil water sensors and stationary thermal infrared thermometers; 2) develop guidelines for selecting soil water potential trigger points for initiating irrigation based on soil properties; and 3) estimate potential pumping reductions from speed-control irrigation for 50,000 center pivots in Nebraska, with field-level results available on an extension website.

- [Deepak Keshwani](#), Associate Professor, UNL Biological Systems Engineering, for the project: *Integrated modeling and analysis of the Corn-Water-Ethanol-Beef System*.

Masters Student: **Luke Monhollon**, for an M.S. in Biological Systems Engineering

Specific outputs to date include implementation of two simulation scenarios for decision-making and education applications. The first scenario allows users to customize irrigation schedule in response to weather. The second scenario allows users to make nitrogen input decisions. These scenarios were developed to focus on critical decisions made by producers. These decisions are framed as multi-faceted, encouraging a broader understanding of the impacts of choices made. While the scenarios are isolated to an individual's decision, the introduction and utilization of the game in the classroom can foster a collaborative environment or a competitive environment.



Luke Monhollon had the opportunity to present our work to representatives from Microsoft who were on campus discussing collaborations with UNL. He also had the opportunity to share his work with Robert and Karla Baltzell at the 2019 DWFI Research Forum.

We are half-way through the NSF grant funding the activities of the project. Based on our assessment, we are on track in terms of delivering a deployable immersive game. We are pilot-testing the educational scenarios this summer with 50 high school teachers to get their feedback.

- **Tiffany Messer**, Assistant Professor, UNL Biological Systems Engineering, for the project: *Understanding Floating Treatment Wetland Potential for Toxic Algal Bloom Prevention in Recreational Lakes*.  
Masters Student: **Mary Keilhauer**, for an M.S. in Hydrological Sciences, Minor in Biosystems Engineering (Graduated May 2019)

Over the past year Ms. Mary Keilhauer has successfully completed her proposed research study, which investigated the nitrogen removal potential of floating treatment wetlands (FTW) and placement in the Midwestern recreational waters. Three greenhouse experiments were conducted throughout the growing season using 18 mesocosms. Nitrate-N removal increased throughout the establishment growing season in the FTW systems (Beginning: 15.0-17.3%, Middle: 82.8- 92.6%, End: 86.4-94.7). A lake mapping method was created to efficiently position and utilize FTW based on existing lake conditions (i.e., dissolved oxygen, oxidation reduction potential, water temperature, and total dissolved solids) for management goals. This lake monitoring assessment technique is anticipated to be utilized for in-situ Best Management Practice (BMP) implementation by providing recommendations for ideal placements based on water quality and physical conditions within waterbodies.



The MESOWheels program has been acquired by Nebraska Extension, the UNL Engineering Ambassadors Program, and Lincoln Public Schools (LPS) after creating and launching two additional hands-on experiences, which focused on pollutant removal and wetlands. Training workshops were provided to several high school groups throughout the state of Nebraska along with LPS and Dimensions Education Nature Explore Pre-K program. Presentations regarding findings from this project were provided for the Nebraska Department of Environmental Quality, Nebraska Natural Resource Districts, and Nebraska Games and Parks.

**Presentations:**

Two (2) oral presentations and four (4) poster presentations

**Publications:**

One peer-reviewed journal article currently under review for a special wetland collection in the journal Transactions of the American Society of Agricultural and Biological Engineering.



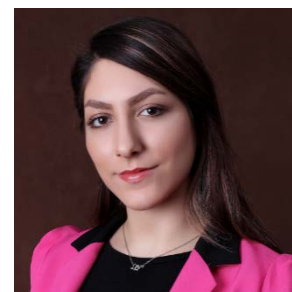
*Floating Treatment Wetland greenhouse experiment*

**Changes in Knowledge/Action:** In May 2019, Mary successfully defended her Master's thesis and in June 2019 she started in a Civil Engineering I position at MIG, an engineering consulting firm in Denver, CO. The method developed to identify placement for in-situ management practices in waterbodies along with the addition of floating treatment wetlands to the Nebraska best management practice manual is currently being considered by the Nebraska Department of Environment and Energy. Negotiations are currently underway for a full scale demonstration at the Wilderness Ridge Golf Course. Lastly, findings from the project assisted in the acquiring a EPSCOR First Award led by Tiffany Messer and an USDA NIFA Foundational grant lead by Shannon Bartelt-Hunt to study the treatment potential of floating treatment wetlands for agricultural pesticides and antibiotics, respectively.

- **Siamak Nejati**, Assistant Professor, UNL Chemical & Biomolecular Engineering, for the project: *Synthesis and Development of the Task-specific Nitrate Adsorbents*.  
Ph.D. Student: **Elham Tavakoli**, for a Ph.D. in Chemical & Biomolecular Engineering

Ion exchange process is one of the most efficient approaches to remove NO<sub>3</sub>-N. However, there has been very little progress in increasing the selectivity of ion-exchange materials for nitrate adsorption in the presence of other ions such as sulfates, chloride and phosphate. In this work, a practical approach is proposed to synthesize ion-exchange materials with enhanced selectivity for nitrate adsorption in water, in the presence of other ions. This project aims to: 1) enable the synthesis of a novel adsorbents based on green chemistry and biodegradable polymers such as chitosan, alginate, and polystyrene, 2) increase the selectivity of the adsorbents for nitrate adsorption in aqueous solutions, and 3) design and develop an approach to enhance the processability and performance of adsorbent. The goal of this research is to meet the institute mission by developing new materials that allow for preserving our water resources. Our objective is to remove contaminant at the source before they enter our water cycles. Research activities conducted to date include:

- Investigating the characteristics of the adsorption behavior of a commercial ion exchange resin, Purolite A600E.





- Synthesizing a new crosslinking agent and cross-linked adsorbent. We focused on the design and synthesis of novel adsorbent based on polystyrene backbone.

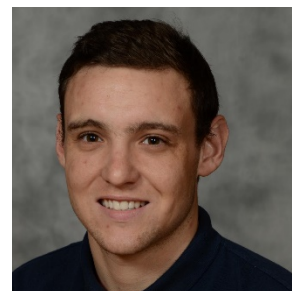
Changes in Knowledge/Action: This project introduces an innovative approach to ion-exchange material development designed for nitrate removal from contaminated water resources. The proposed method leads us toward material development, enabling us to selectively remove nitrate in the presence of other ions.

- **Amy Millmier Schmidt**, Associate Professor, UNL Biological Systems Engineering & Animal Science, for the project: *Transforming Manure and Cedar Mulch from “Waste” to “Worth.”*

Masters Student: **Agustin José Olivo**, for an M.S. in Biological Systems Engineering

This project, launched on July, 2018, involves over 40 individuals representing four state organizations and six natural resource districts (NRDs) in Nebraska (Fig. 1) who are committed to:

1. Documenting and demonstrating the agronomic, economic, environmental and soil health benefits of woody biomass and manure as soil amendments through on-farm research in cooperation with commercial crop producers statewide;
2. Increasing high school student science literacy by engaging students in on-farm research and delivery of new knowledge to the agricultural community and peers; and
3. Motivating crop farmers to utilize cedar tree mulch and manure on cropland through a statewide communication strategy to improve understanding of the benefits of these products as soil amendments.



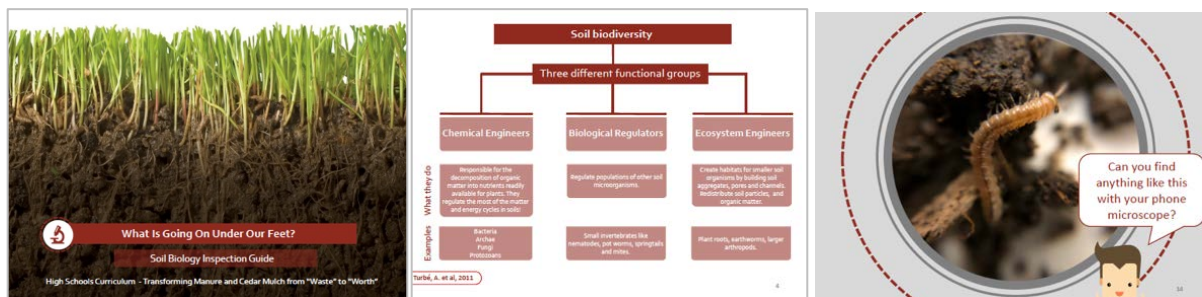
Local implementation teams comprised of at least one member of the participating NRD and one Nebraska Extension educator in the NRD were formed to optimize local management and communication about the project. Each team successfully identified a local crop farmer with whom to conduct on-farm research and at least one local high school agriculture program with which the project team is engaging throughout the project. Soil sampling was completed and plots established at five study sites. Treatments using cedar mulch and manure were applied to plots near St. Paul, NE, Ainsworth, NE, Brule, NE, and Pierce, NE; applications at the remaining on-farm study sites will progress as weather permits.

Presentations:

- Daugherty Water for Food Global Conference, Lincoln, Nebraska, April 29 – 30, 2019
- Waste-to-Worth Conference, Minneapolis, Minnesota, April 22 – 26, 2019
- Daugherty Water for Food Institute Research Forum Poster Session, Lincoln, Nebraska, April 4, 2019

Changes in Knowledge/Action: A 52-page *Soil Biology Inspection Guide* and a 170-page *High School Curriculum* were authored by graduate research assistant, Agustin Olivo, whose work is supported by the *Robert and Karla Baltzell Student Innovator Fund*, awarded by the *Robert B. Daugherty Water for Food Global Institute* during the current project year. The *Soil Biology Inspection Guide* is intended to assist students in identifying and understanding the roles of soil organisms that they find during hands-on soil inspections with a smart phone microscope.

Several of the cooperating high school partners have begun delivering at least one curriculum module and all are expected to deliver curricula in fall 2019.



Sample pages from the *Soil Biology Inspection Guide* developed for high school partners.

- **Bing Wang**, Assistant Professor, UNL Food Science & Technology, for the project: *Treatments for Water Used at Pre-harvest Stage to Mitigate Human Exposure to Microbial Hazards through Consumption of Frozen and Fresh Raspberry in Chile*. Project on hold pending enrollment of M.S. student.
- **John (Kalu) Osiri**, Associate Professor of Practice, UNL College of Business & **Michael Hayes**, Professor, UNL School of Natural Resources, for the project: *Exploring Opportunities to Incorporate Climate Information into Stakeholder Decision Making in Sub-Saharan Africa*. Masters Student: **Azariah Lawal**, for a M.S. in Natural Resources.

Azariah began his research project in January 2019. He has proposed a thesis titled, “A Comparative Analysis of Farmers’ and Agricultural Entrepreneurs’ Resilience to Climate Change in Nebraska and West Africa.” Azariah has begun the IRB process needed to prepare for stakeholder interviews as part of this project, and he has begun the literature review necessary to create metrics of sustainability that can be used in the agricultural communities and will be assessed from the stakeholder interviews. The goal of these interviews is to ascertain the resiliency of the farmers and agricultural business entrepreneurs to climate change and to compare them to their Nebraska counterparts. It is hoped that lessons learned can be shared so that agricultural resilience can be strengthened. A survey instrument will be developed during the summer of 2019. Study participants will be from Nebraska and southeastern Nigeria, Benin and Ghana.



#### Presentations:

1. DWFI Faculty-Student Research Forum on April 4, 2019, entitled “Responding to Global Food Insecurity Due to Climate Variation.”
2. DWFI Global Conference on April 30, 2019, entitled “Developing Sustainable Irrigation Systems in Africa: A Multidisciplinary Approach for Designing Solar-Powered Center Pivot.”

Changes in Knowledge/Action: TBD